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THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC)

A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials

March 1980

Center for Information and Numerical Data Analysis and Synthesis
Purdue University
West Lafayette, Indiana 47906

Annual Final Report - Contract DLA900-79-C-1007

Approved for public release; distribution unlimited.

Prepared for

ARMY MATERIALS AND MECHANICS RESEARCH CENTER
Watertown, Massachusetts 02172

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This Annual Final Report on Contract No. DLA900-79-C-1007 covers the activities and accomplishments of the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) for the period 1 January to 31 December 1979. TEPIAC's activities reported herein include literature search, acquisition, and input of source information; documentation review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction

20. ABSTRACT (continued)

and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. TEPIAC is one of the most efficient and cost-effective Full-Service Information Analysis Centers when evaluated on input and output volumes per budgeted dollar. During this 12-month reporting period, TEPIAC screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 research documents while completely overhauled the computerized bibliographic information system, extracted and compiled 2,675 sets of property data from 842 data source documents by processing 2,148 research documents in addition to performing data evaluation, correlation, analysis, and synthesis and generating recommended reference values, and responded to 562 inquiries from government laboratories and agencies, defense contractors and other industrial organizations, and academic institutions. Furthermore, under multiple sponsorship four volumes of data books of the new <u>CINDAS Data Series on Material Properties</u> with a total of 1,553 pages and another data book with 280 pages were completed. Two state-of-the-art reports with a total of 396 pages were completed and released, three state-of-the-art reports completed previously were published in the Journal of Physical and Chemical Reference Data, ten volumes of research literature retrieval guides and supplements with a total of 3,097 pages were published, six issues of the "Thermophysics and Electronics Newsletter" with a total of 66,000 copies and three promotional brochures with a total of 9,000 copies were distributed. TEPIAC sponsored two international conferences and TEPIAC staff participated in fourteen other conferences and meetings. A promotional and documentary film entitled "The Anatomy of Data" produced previously has been shown to about 184 organizations.

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SUMMARY

The Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) is a Full-Service Department of Defense Information Analysis Center operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University under contract with the Defense Logistics Agency (DLA) and under the technical direction of the Army Materials and Mechanics Research Center (AMMRC). The objective of TEPIAC operations is to increase the productivity of scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense by maintaining a comprehensive, authoritative, and up-to-date national data base on thermophysical and electronic (including also electrical, magnetic, and optical) properties of materials for use by the entire DOD community and by providing authoritative data and information analysis services. Its major functions are to search, collect, review, evaluate, appraise, analyze, synthesize, and summarize the available scientific and technical data and information from worldwide sources on the various thermophysical, electronic, electrical, magnetic, and optical properties of materials and to disseminate the results both by providing authoritative data and information directly to the individual users through technical and bibliographic inquiry services and by publishing major reference works on property data and information for the general users at large.

TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments.

This Annual Final Report on Contract No. DLA900-79-C-1007 covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported herein include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts.

TEPIAC is one of the most efficient and cost-effective Full-Service Information Analysis Centers when evaluated on input and output volumes per budgeted dollar. During this 12-month reporting period, the Center screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 research documents while completely overhauled the computerized bibliographic information system, extracted and compiled 2,675 sets of property data from 842 data source documents by processing 2,148 research documents in addition to performing data evaluation, correlation, analysis, and synthesis and generating recommended reference values, and responded to 562 inquiries from government laboratories and agencies, defense contractors and other industrial organizations, and academic institutions. Furthermore, under multiple sponsorship four volumes of data books of the new CINDAS Data Series on Material Properties with a total of 1,553 pages and another data book with 280 pages were completed. Two state-of-the-art reports with a total of 396 pages were completed and released, three state-of-the-art reports completed previously were published in the Journal of Physical and Chemical Reference Data, ten volumes of research literature retrieval guides and supplements with a total of 3,097 pages were published, six issues of the "Thermophysics and Electronics Newsletter" with a total of 66,000 copies and three promotional brochures with a total of 9,000 copies were distributed. TEPIAC sponsored two international conferences and TEPIAC staff participated in fourteen other conferences and meetings. A promotional and documentary film entitled "The Anatomy of Data" produced previously has been shown to about 184 organizations. A statistical summary of TEPIAC accomplishments is presented in Table 1.

TABLE 1. STATISTICAL SUMMARY OF TEPIAC ACCOMPLISHMENTS

(For the Period 1 January to 31 December 1979)

	This Period	Total as of 31 December 1979
Scope		
Properties covered	36	36
Materials covered	39,741	39,741
Scientific Documentation		
Abstracts screened	750,000	43,960,000
Relevant abstracts scrutinized	46,000	758,300
Pertinent documents identified	11,400	222,200
Documents on hand	17,634	183,331
Documents reviewed, coded, and catalogued	1,837	153,382
Entries of codification	[a]	557,085[a]
Sources of documents	8,630	8,630
Data Table Generation		
Documents processed	2,148	44,855
Data source documents resulted	842	20,496
Data sets compiled	2,675	93,713
Data sets in the Evaluated Numerical Data Bank	---	4,268
Inquiry Services		
Inquiries from government laboratories and agencies	69	1,091[b]
Inquiries from defense contractors and other industrial organizations	357	4,007[b]
Inquiries from academic institutions	136	2,046[b]
Total inquiries	562	7,144[b]
Publications		
Research Literature Retrieval Guides and Supplements		
Number of volumes	10	19
Number of pages	3,097	8,258
Data Books and Handbooks		
Number of volumes	5	29
Number of pages	1,833	30,514
State-of-the-art reports and technical reports		
Number of reports	2	31
Number of pages	396	5,012
Masters Theses in the Pure and Applied Sciences		
Number of volumes	1	23
Number of pages	292	5,153
Current Awareness and Promotion Efforts		
Thermophysics and Electronics Newsletter		
Number of issues	6	48
Number of copies	66,000	260,100
Promotional brochures		
Number of brochures	3	19
Number of copies	9,000	51,650
Conferences and meetings		
Number of conferences and meetings sponsored	2	16
Number of conferences and meetings participated	14	145
Documentary film	---	1

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[a] See footnotes b and c to Table 2 on page 9.
[b] Since 1963.

PREFACE

This Annual Final Report was prepared by the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC), a Department of Defence Information Analysis Center (IAC). This Center is operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana, under Contract No. DLA900-79-C-1007 with the Defense Logistics Agency (DLA), Alexandria, Virginia, with Mr. J. L. Blue being the IAC Program Manager, and under the technical direction of the Army Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts, with Mr. Samuel Valencia being the Contracting Officer's Technical Representative. The Contract was issued by the Defense Electronics Supply Center, Dayton, Ohio, with Mr. S.C. Rosta and Mrs. Frances Burke being the Contracting Officers.

The present Contract is for a period of three years from 1 January 1979 to 31 December 1981. This Annual Final Report covers only the first year from 1 January to 31 December 1979, and was submitted to fulfill the contractual requirement (Item No. 0002, Sequence No. A002).

The work reported herein is credited to the collective efforts of the entire staff of the Thermophysical and Electronic Properties Information Analysis Center. Dr. Y. S. Touloukian, Director of CINDAS, and Dr. C. Y. Ho, Assistant Director-Research, have been the principal investigators.

This report has been reviewed and is approved.

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SECTION I

INTRODUCTION

The Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) is a Department of Defense Information Analysis Center operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University. Under CINDAS' operation, TEPIAC has long achieved the full operational status of a Full-Service DOD Information Analysis Center, and TEPIAC has been well oriented to the needs of its user community with its products and services well-known.

The objective of TEPIAC operations is to increase the productivity of scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense by maintaining a comprehensive, authoritative, and up-to-date national data base on thermophysical and electronic (including also electrical, magnetic, and optical) properties of materials for use by the entire DOD community and by providing authoritative data and information analysis services. Services are also rendered to other U.S. Government Agencies and their contractors and, to the extent practical without impairment of services to the foregoing users, to the private sector, consistent with security and other limitations on TEPIAC's information.

The major functions of TEPIAC are to search, collect, review, evaluate, appraise, analyze, synthesize, and summarize the available scientific and technical data and information from worldwide sources on the various thermophysical, electronic, electrical, magnetic, and optical properties of materials and furthermore to disseminate the results both by providing authoritative data and information directly to the individual TEPIAC users through technical and bibliographic inquiry services and by publishing major reference works on property data and information for the general TEPIAC users at large.

TEPIAC's major tasks and activities include literature search, acquisition, and input of source information for maintaining the data base; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; technical and bibliographic inquiry services; and current awareness and promotion efforts.

While TEPIAC is a full-service IAC, it has traditionally stressed data evaluation and analysis and the generation of reference data more than any other single group anywhere. Furthermore, it has always felt that the maximum optimization of its efforts in serving the end users of data and information can best be realized through the publication of major reference works, whereby the data and information are readily available at arm's reach of the engineers, scientists, and technicians. Towards this end, TEPIAC has contributed greatly over the years by publishing a number of the most comprehensive and authoritative series of data books and handbooks published anywhere.

It is appropriate at this point to discuss briefly the importance of the knowledge of thermophysical, electronic, electrical, magnetic, and optical properties of materials covered by TEPIAC to the mission of the Department of Defense and the important role of Information Analysis Centers such as TEPIAC in national defense. There is no doubt that the knowledge of material properties is extremely important to the mission of the Department of Defense because the proper design of defense systems and military weapons, hardware, equipment, structures, etc. used in national defense requires a complete knowledge of the properties of materials. Consider first an example that concretely demonstrates the importance and usefulness of such knowledge to the Department of Defense and, as a consequence, that the mission of the Department of Defense is accomplished in a most competent manner with such knowledge. It is well known that a thorough knowledge of thermal conductive and radiative properties of refractory, insulation, and other aerospace materials is a fundamental requirement of the design of advanced weapons such as balistic missiles and spacecraft which require thermal protection systems for their operating at extremes in temperature and require lightweight high-efficiency thermal insulation systems for cryogenic fuel in booster applications. The thermal conductive and radiative properties of refractory and composite materials used in nose cones, nozzles, and leading edges are so important that these properties determine directly the temperature level of operation, and furthermore, together with thermal expansion they determine the thermal stress and thermal shock characteristics, which are most important design considerations for high temperature applications. In short, without the knowledge of these properties, the design of spacecraft, balistic missiles, and all other similar warhead delivery systems would not have been possible, and this Nation's advanced defense systems and space programs could not be off the ground.

For the design of conventional military vehicles, tanks, airplanes, and warships or their power-plants and of various firearms ranging from small guns to heavy artilleries, the knowledge of thermal conductive, radiative, and other thermophysical properties is also very essential because their operations always involve rapid heat generation and high thermal stress and thus require efficient heat dissipation or cooling; all such processes are directly related to thermophysical properties of the materials used. Thermophysical properties of fluids are important in the design of engine cooling system, lubricating system, fuel system, combustion and exhaust system, etc. For the design of nuclear engine used in a submarine or warship, the knowledge of the thermophysical properties of nuclear fuel materials and fuel rod cladding materials is essential since these properties determine the maximum attainable heat flux from fuel rods and the temperature level of operation, which dictate almost the entire design.

In the current advanced technology, the knowledge of thermal radiative properties as well as optical properties is most essential both in the development of high-power laser weaponery for destroying enemy's aircrafts, missiles, satellites, etc. and in the development of laser-hardened materials for protecting our aircrafts, missiles, satellites, etc. against enemy's high-power laser attack. The knowledge of thermal radiative and optical properties is also extremely important in the development of target signature recognition systems for detecting and identifying enemy's oncoming aircrafts and missiles and for identifying terrestrial objects in guidance and reconnaissance applications.

The knowledge of electronic, electrical, and magnetic properties of materials is, of course, essential for the design of all electronic devices and equipment for military applications, including, for example, those electronic devices used in military electronic communication, electronic high-speed computation, electronic guidance, control, and tracking, electronic detection and sensing, electromagnetic memory and recording, electronic surveillance, reconnaissance, and intelligence, electronic jamming, deception, and countermeasure, and those military electronic devices for energy generation, storage, conversion, and transmission. In fact, the rapid advance in electronic gadgetry in recent years is a direct result of increased knowledge of the electronic, electrical, and magnetic properties of materials, unusual or otherwise. In electronic devices, the availability of efficient heat sinks for micro-circuits is another essential requirement for their satisfactory performance, and the design of efficient heat sinks requires the knowledge of thermophysical properties. It is indeed an endless list of examples demonstrating the great importance and usefulness to the Department of Defense of the knowledge of thermophysical, electronic, electrical, magnetic, and optical properties, of which TEPIAC is responsible for coverage.

In the past, the data and information on the properties of materials, though so important, were buried in the world's enormous and ever-expanding volume of scientific and technical literature, and the scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense used no more than a small fraction of the data and information already existing. This disturbing situation has been gradually improved since the establishment of the scientific and technical Information Analysis Centers, such as TEPIAC, by the Department of Defense. TEPIAC has been conducting a continuing systematic program to dig the buried data and information and to screen and filter the current data and information out of the world's ever-increasing volume of literature and to critically evaluate, appraise, analyze, synthesize, summarize, and put the data and information in a form most useful to the users in the entire Defense community. There is no doubt that the more accurately the properties of materials are known, the more likely that a system can be designed properly and performed successfully, and that the more readily the property data and information are available, the more likely that a development program can be expedited.

The important role of TEPIAC, or of any other DOD Information Analysis Center, in national defense is to assure that the Department of Defense carries out its mission timely and most effectively by serving as a focal point for authoritative expertise and maintaining a national data base within the scope of its coverage to be tapped by the Department of Defense and its contractors for solutions to technological problems and for the planning of advanced defense systems, by providing instant response to meet urgent requirements of the Department of Defense when short reaction time is essential, by serving as a vehicle for effective technology transfer within its scope, thus closing the time gap between R & D and application, by having complete cognizance of the topography of the state of knowledge within its scope, thus able to quickly identify areas where knowledge is lacking and research is required to meet existing needs and anticipated future demands, and by bringing about significant cost savings to the Department of Defense and others by preventing the use of erroneous input data in critical technical applications and avoiding duplication in present and future research efforts. In short, TEPIAC and other DOD Information Analysis Centers play a very significant role in our national defense.

CINDAS, who operates TEPIAC, is a part of Purdue University, which is one of the leading institutions of higher learning in the Nation. Purdue University has numerous research laboratories in all fields and disciplines and many of these are for the measurement and research on thermophysical and/or electronic properties. Furthermore, there are over 2500 highly-trained faculty members and research specialists at Purdue. When the need arises CINDAS/TEPIAC can draw on their scientific and engineering expertise with immediate access.

Due to the fact that CINDAS' own staff, with its 13 doctoral level professional personnel, possess a very high degree of expertise in thermophysical and electronic properties, material science, solid state physics, physical chemistry, and spectroscopy, the assistance from outside CINDAS is, therefore, seldom needed. CINDAS/TEPIAC' staff have an enviable performance record of scientific and professional accomplishments through original research contributions to the primary literature. Thus they possess a high level of professional recognition and credibility in their work, which is absolutely essential for acceptance by their peers. Some of the staff have received honors and distinctions from National and International scientific and technical bodies. In the area of scientific documentation its staff comprise highly trained personnel (several staff having a degree of Master of Science) with an average of over 12 years experience in their speciality. On its premises CINDAS has an experimental research laboratory for the measurements of thermophysical and electronic properties which is recognized as a most outstanding laboratory with a wide range of "state-of-the-art" capabilities. The work of this laboratory contributes directly to the data evaluation and analysis process, which constitutes a unique and invaluable asset to TEPIAC.

TEPIAC's accomplishments in all its tasks and activities in the performance of this contract for the 12-month period from 1 January 1979 to 31 December 1979 are detailed in the following sections.

SECTION II

SCIENTIFIC DOCUMENTATION ACTIVITIES

In order to maintain a comprehensive, authoritative, and up-to-date national data base on thermophysical, electronic, electrical, magnetic, and optical properties of materials and to provide authoritative information and data to the users with instant retrieval capability, TEPIAC has maintained a systematic program of literature search and acquisition, document review and codification, material classification, information organization, and of storing the resulting information in a computerized information storage and retrieval system. The various phases of activities in this program are discussed below.

1. LITERATURE SEARCH, ACQUISITION, AND INPUT OF SOURCE INFORMATION

The fourteen thermophysical properties under TEPIAC cognizance of information and data in all pertinent subject areas are as follows:

1. Thermal conductivity
2. Accommodation coefficient
3. Thermal contact resistance
4. Thermal diffusivity
5. Specific heat at constant pressure
6. Viscosity
7. Emittance
8. Reflectance
9. Absorptance
10. Transmittance
11. Solar absorptance to emittance ratio
12. Prandtl number
13. Thermal linear expansion coefficient
14. Thermal volumetric expansion coefficient

Originally two more properties (diffusion coefficient and surface tension) had been monitored, but these were dropped in mid-1970.

The fifteen specific electronic, electrical, magnetic, and optical properties and seven property groups under TEPIAC cognizance of information and data in all pertinent subject areas are as follows:

Properties

1. Absorption coefficient
2. Dielectric constant
3. Dielectric strength
4. Effective mass
5. Electric hysteresis
6. Electrical resistivity
7. Energy bands
8. Energy gap
9. Energy levels
10. Hall coefficient
11. Magnetic hysteresis
12. Magnetic susceptibility
13. Mobility
14. Refractive index
15. Work function

Property Groups

16. Electron emission properties
    a. Field emission
    b. Photoemission
    c. Secondary emission
    d. Thermionic emission

17. Luminescence properties
    a. Cathodoluminescence
    b. Electroluminescence
    c. Mechanical luminescence
    d. Photoluminescence
    e. Thermoluminescence

18. Magnetoelectric properties
    a. Ettingshausen effect
    b. Magnetoresistance
    c. Nernst effect
    d. Shubnikov-de Haas effect

19. Magnetomechanical properties
    a. Anisotropy energy
    b. Magnetostriction

20. Photoelectronic properties
    a. Dember effect
    b. Photoconductivity
    c. Photomagnetic effect
    d. Photopiezoelectric effect
    e. Photovoltaic effect

21. Piezoelectric properties
    a. Piezoelectric effect
    b. Pyroelectric effect

22. Thermoelectric properties
    a. Peltier effect
    b. Seebeck effect
    c. Thomson effect

As to material coverage in this documentation phase of the program, TEPIAC covers nearly all materials at all temperatures and pressures and in all environments, which are far more than what are required by the contract. The materials required by the contract to be covered for thermophysical properties include, as a minimum, metals and metal alloys, ceramics, cermets, intermetallics, polymers, and composites, and those for electronic (including also electrical, magnetic, and optical) properties to be given priority coverage include elements, inorganic compounds, alloys, intermetallics, glasses, ceramics, cermets, applied coatings, polymers, composites, and systems.

The strategy of literature search has been to use both the abstracting journals and the scientific and technical journals. A number of selected journals have been subscribed and hundreds of the journals subscribed by Purdue Libraries have been fully utilized. The top ten high-yield scientific and technical journals for thermophysical properties are noted below:

1. Physical Review
2. Journal of Chemical Physics
3. Journal of Applied Physics
4. Russian Journal of Physical Chemistry
5. Soviet Physics - Solid State
6. Inorganic Materials (USSR)
7. Physica Status Solidi
8. Applied Optics
9. High Temperature (USSR)
10. Solid State Communications

The top ten high-yield scientific and technical journals for electronic properties are as follows:

1. Journal of Applied Physics
2. Soviet Physics - Semiconductors
3. Physica Status Solidi
4. Physical Review
5. Soviet Physics - Solid State
6. Solid State Communications
7. Physics Letters
8. Journal of Physical Society of Japan
9. AIP Conference Proceedings
10. Japanese Journal of Applied Physics

In addition to searching selected technical journals, four abstracting journals covering the open literature and four government abstracting journals covering the government report literature are monitored. These are:

1. Chemical Abstracts
2. Physics Abstracts
3. Electrical and Electronics Abstracts
4. Dissertation Abstracts International
5. Scientific and Technical Aerospace Reports (NASA)
6. Technical Abstracts Bulletin (DDC)
7. U. S. Government Reports Announcements (NTIS)
8. Technical Translations (NTIS)

In monitoring these abstracting journals, computer-screened inputs have been used. About 750,000 abstracts were screened by computer using carefully designed search logics. These basic sources and other minor sources yielded approximately 46,000 hits in this 12-month period. These 46,000 potentially good entries were further scrutinized manually to yield 4,100 pertinent references on thermophysical properties and 7,300 pertinent references on electronic properties. This and other statistical data showing TEPIAC's overall scientific documentation accomplishments in this period are presented in Table 2. Table 2 shows that 98,500 research documents on thermophysical properties and 123,700 research documents on electronic, electrical, magnetic, and optical properties

TABLE 2. STATISTICAL SUMMARY OF SCIENTIFIC DOCUMENTATION ACCOMPLISHMENTS

Thermophysical Properties

	Total as of 31 Dec. 1978	This Period	Total as of 31 Dec. 1979
Potential abstracts further scrutinized	---	18,000	---
Documents identified (references in system)	94,400	4,100	98,500
Documents on hand (microfiches and hard copies)	87,383	6,091	93,474
Documents reviewed, coded, and catalogued	76,190	868[a]	77,058
Codification entries on all properties	---	---	316,516[b]

Electronic Properties

	Total as of 31 Dec. 1978	This Period	Total as of 31 Dec. 1979
Potential abstracts further scrutinized	---	28,000	---
Documents identified (references in system)	116,400	7,300	123,700
Documents on hand (microfilms, microfiches, and hard copies)	78,314	11,543	89,857
Documents reviewed, coded, and catalogued	75,355	969[a]	76,324
Codification entries on all properties	---	---	113,569[b,c]

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[a] Work in this area was temporarily reduced in order that the staff could overhaul and merge the two separate thermophysical properties information file and electronic properties information file into a single uniform Thermophysical and Electronic Properties Information System. In addition, efforts were expended to produce ten new retrieval guide volumes with a total of 3,097 pages.

[b] In the restructuring and merging of the files, some codification entries were eliminated, resulting in the net totals as shown.

[c] Not including the estimated 127,000 codification entries for the 49,300 documents processed before 1973 by the former EPIC. If including those, the total number of codification entries should be 240,569.

have been identified and selected for the TEPIAC data base as of 31 December 1979. It is expected that on the average about 4,000 to 4,500 research documents on thermophysical properties and 6,000 to 8,000 research documents on electronic, electrical, magnetic, and optical properties will be added to the TEPIAC data base each year.

In addition to the basic sources, TEPIAC has searched certain specialized sources such as special bibliographies, compendia, conference proceedings, symposium volumes, and listings of doctoral dissertations and master theses. Of particular note is the Kobe Affiliate[a] of CINDAS at Kobe, Japan, who has served a very important input function for Far Eastern literature. Furthermore, TEPIAC has continued to develop its cooperative working arrangements on the exchange of research results and information with major national and international laboratories and institutions engaged in thermophysical and/or electronic properties research. Through these highly developed procedures and arrangements, TEPIAC has a high level of confidence in regard to completeness of its input of source information.

Recent statistics shows that research documents on thermophysical and electronic properties come from the following major sources:

	Percent
Journal articles from Purdue library subscriptions	55.6
Journal articles from TEPIAC subscriptions	9.1
Journal articles from authors	17.5
Journal articles from Library of Congress	7.2
Government reports from DDC	5.8
Government reports from NTIS	2.9
Ph.D. dissertations and M.S. theses	0.8
Other sources	1.1
Total	100%

The above listing indicates that scientific and technical journal articles and other open literature constitute about 91 percent of the total research documents and government reports constitute only about 9 percent.

TEPIAC's specialized holdings of research documents, which number 93,474 on thermophysical properties and 89,857 on electronic properties as of 31 December 1979 as shown in Table 2, constitute a unique national asset and are assuming increasing importance for rapid access to the world literature on thermophysical and electronic properties. Many of these research documents, though readily available from TEPIAC, are very difficult to obtain elsewhere especially in the

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[a] This CINDAS' overseas affiliate is supported through other sources.

cases of foreign literature and special publications of limited distribution. It is our experience that literature retrieval programs which yield only bibliographies as their end product are becoming increasingly less useful because of the difficulty and time lapse involved in procuring the cited documents. To remedy this situation, TEPIAC has long been supplementing the practice of submitting bibliographic responses to literature search requests with copies of the actual documents in the form of standard microfiche or hard copy.

2. DOCUMENT REVIEW AND CODIFICATION, MATERIAL CLASSIFICATION, AND INFORMATION ORGANIZATION

As each pertinent research document was received, it was immediately microfiched and then thoroughly reviewed. Pertinent information was extracted from the document with respect to the particular property measured or treated and the temperature range, the material tested and its physical state, the subject coverage of the document, and the language used. All these except the material name were translated into mnemonic code letters, and the material was assigned a material number according to an established material classification scheme. The code letters, material number, and document number were recorded on a specially designed Coding Form (see Figure 1), and were processed subsequently by computer for storage and retrieval, and also for publication of the Research Literature Retrieval Guides. The code designations for codification of literature are given in Table 3.

The number of documents reviewed and coded for retrieval was temporarily reduced because major efforts were expended to overhaul and merge the two separate thermophysical properties bibliographic information file and electronic properties bibliographic information file into a single uniform bibliographic information system hereafter referred to as the Thermophysical and Electronic Properties Information System (TEPIS). This approach is in line with our constant efforts to improve the effectiveness of our operations and should prove to be more convenient to the defense community which we serve as this merging will make it possible for scientists and engineers to access the total TEPIAC system with greater ease and in a uniform manner. Due to this diversion of efforts, only 1,837 documents on both thermophysical and electronic properties were reviewed, coded, and catalogued, as indicated in Table 2. In the restructuring and merging of the files, some codification entries were eliminated,

Figure 1.

TECHNICAL CODING FORM

CODED BY: ____________

DATE: ____________

PAGE No. (columns 38, 40, 41, 42, 43, 44)

PROP	CLASS	SUBST	MC	D	PS	S	T	L	DOCUMENT No.	YEAR	A	O	
X													Property letter
	XXX												Substance class number
		XXXX											Substance number
			X										Mixture code letter
				X									Dopant number
					X								Physical state letter
						X							Subject letter
							X						Temperature letter
								X					Language letter
									XXXXXX				Document number
										XXX			Year of publication
											X		Abstract code letter
												X	Operation column
H	122	0016			S	D	N	E	T069904	973			V_2O_5 Vanadium Oxide (For Thermophysical Properties)
AS	122	0016			S	D	N	E	E100961	973	H		V_2O_5 Vanadium Oxide (For Electronic Properties)

TABLE 3. CODE DESIGNATIONS FOR CODIFICATION OF LITERATURE

Thermophysical Properties

A - Thermal conductivity
B - Accommodation coefficient
C - Thermal contact resistance
D - Thermal diffusivity
E - Specific heat at constant pressure
F - Viscosity
G - Emittance
H - Reflectance
I - Absorptance
J - Transmittance
K - Absorptance to emittance ratio
L - Prandtl number
N - Thermal linear expansion coefficient
O - Thermal volumetric expansion coefficient

Electronic Property

AS-Absorption coefficient
DC-Dielectric constant
DS-Dielectric strength
EB-Energy band
EF-Effective mass
EG-Energy gap
EH-Electric hysteresis
EL-Energy level
ER-Electrical resistivity
HC-Hall coefficient
MH-Magnetic hysteresis
MO-Mobility
MS-Magnetic susceptibility
RI-Refractive index
WF-Work function
EP-Electron emission properties
GP-Magnetoelectric properties
LP-Luminescence properties
MP-Magnetomechanical properties
PP-Photoelectronic properties
TP-Thermoelectric properties
ZP-Piezoelectric properties

Dopant

1-Group IA & IB
2-Group IIA & IIB
3-Group IIIA
4-Group IVA
5-Group VA
6-Group VIA
7-Group VIIA & VIIIA
8-Group IVB, VB, VIB, VIIB, & VIII
9-Group IIIB, Lanthanide Series, Actinide Series
0-Other or unspecified

Physical State

C-Superconductive
D-Doped
E-Expanded
F-Fibrous or whisker
G-Gas
I-Ionized (plasma)
L-Liquid
M-Multiphase
P-Powder or fine particle
S-Solid
T-Thin or thick film

Temperature

L-Low (0 to 75 K)
N-Normal (above 75 K to 1273 K) or unspecified
H-High (above 1273 K)
F-Low + Normal + High

Form of Document

A-Coded from abstract
B-Coded from abstract, document available
H-Coded from hard copy
M-Coded from microform (microfiche or microfilm)
T-Coded from translation

Subject

D-Data
E-Experiment
G-Experiment + Theory + Data
S-Survey, review, compendium, data compilation, etc.
T-Theory

Language

C-Czechoslovakian
D-Dutch
E-English
F-French
G-German
I-Italian
J-Japanese
O-Other
P-Polish
R-Russian
S-Spanish

which resulted in a net total of 316,516 codification entries on thermophysical properties and 113,569 codification entries on electronic properties as of 31 December 1979. The latter number does not include the estimated 127,000 codification entries on electronic properties for the 49,300 documents processed before 1973 by the former EPIC. One codification entry represents usually one property of one material.

Tables 4 and 5 show the file composition for thermophysical and electronic properties, respectively, by indicating the percentages of codification entries of the various properties with respect to the total number of entries. It is noted that the percentages of codification entries for most of the properties remain fairly constant over the years.

The organization of the thermophysical and electronic properties information is by material, and thus a sound material classification scheme which can properly accommodate all materials and substances is very important. The established material classification scheme has been designed to accommodate materials and substances into similar groups, selected preferably by their chemical composition. However, because of their inherent nature, certain materials do not lend themselves to a purely chemical classification and a more logical method has been adopted to classify them, instead, by their physical form and/or use and application. The present classification scheme has been used successfully over the years for the classification of approximately 40,000 different materials and substances, for which information is available in the TEPIAC file. The end product is a most comprehensive Materials Directory, which is generated by computer.

3. COMPUTERIZED BIBLIOGRAPHIC INFORMATION STORAGE AND RETRIEVAL SYSTEM

The newly completed computerized Thermophysical and Electronic Properties Information System has been in full operation. By using the CDC 6500 and 6600 computer facility at Purdue University, to which TEPIAC is connected with three dedicated terminals, this new information storage and retrieval system is being used by TEPIAC to provide bibliographic searches for both thermophysical and electronic properties in response to specific inquiries. This new system has reduced operating costs, eliminated manual procedures, assured integrity of the information, and provided a more flexible, powerful, and responsive search capability.

TABLE 4. THERMOPHYSICAL PROPERTIES FILE COMPOSITION

Property	% File
Thermal conductivity	26.9
Accommodation coefficient	0.6
Thermal contact resistance	0.7
Thermal diffusivity	2.5
Specific heat at constant pressure	24.1
Viscosity	17.6
Emittance	2.9
Reflectance	5.6
Absorptance	1.2
Transmittance	3.7
Absorptance to emittance ratio	0.2
Prandtl number	0.5
Thermal linear expansion coefficient	8.3
Thermal volumetric expansion coefficient	1.0
Thermal radiative properties	4.1
	100%

Subject	% File
Data	67.5
Experiment	5.5
Theory	15.1
Experiment + Theory + Data	6.8
Survey, review, compendium, *data compilation, etc.*	5.2
	100%

Temperature Range	% File
Low (0 to 75 K)	9.1
Normal (above 75 K to 1273 K)	62.6
High (above 1273 K)	12.0
Full range (Low + Normal + High)	0.9
Unspecified	15.4
	100%

Physical State	% File
Solid	53.3
Liquid	23.7
Gas	15.7
Doped	1.1
Expanded	0.4
Fibrous or whisker	0.3
Powder or fine particle	2.4
Multiphase	2.9
	100%

Language	% File
English	71.2
Czechoslovakian	0.1
Dutch	0.2
French	2.8
German	7.4
Italian	0.6
Japanese	1.3
Polish	0.1
Russian	15.4
Spanish	0.2
Others	0.8
	100%

TABLE 5. ELECTRONIC PROPERTIES FILE COMPOSITION

Property	% File
Absorption coefficient	7.6
Dielectric constant	4.2
Dielectric strength	0.8
Energy bands	2.1
Effective mass	1.2
Energy gap	4.9
Electric hysteresis	0.3
Energy levels	5.5
Electron emission properties	2.3
Electrical resistivity	35.2
Magnetoelectric properties	2.0
Hall coefficient	2.6
Luminescence properties	3.2
Magnetic hysteresis	2.4
Mobility	2.8
Magnetomechanical properties	0.9
Magnetic susceptibility	6.4
Photoelectronic properties	1.8
Refractive index	5.2
Thermoelectric properties	6.6
Work function	1.6
Piezoelectric properties	0.5
	100%

Subject	% File
Data	52.7
Experiment	4.2
Theory	16.0
Experiment + Theory + Data	1.0
Survey, review, compendium, data compilation, etc.	26.0
	100%

Temperature Range	% File
Low (0 to 75 K)	17.9
Normal (above 75 K to 1273 K) or unspecified	77.0
High (above 1273 K)	4.9
Full range (Low + Normal + High)	0.2
	100%

Physical State	% File
Solid	66.1
Liquid	7.3
Gas	1.1
Doped	12.2
Expanded	0.0
Fibrous or whisker	0.2
Powder or fine particle	0.3
Thin or thick film	8.9
Ionized (plasma)	0.9
Superconducting	3.0
Multiphase	0.0
	100%

Language	% File
English	77.2
Czechoslovakian	0.1
Dutch	0.0
French	1.1
German	2.8
Italian	0.1
Japanese	0.8
Polish	0.2
Russian	17.3
Spanish	0.0
Others	0.4
	100%

The new system is build around an integrated file system which provides for direct access to the desired information; this is in contrast to our previous system which performed all operations in a batch sequential mode. As a result we can more easily cross-check information in the files as well as retrieve information at a lower cost. This new system supplants the original system established some 16 years ago with many subsequent modifications.

4. RESEARCH LITERATURE RETRIEVAL GUIDES AND SUPPLEMENTS

The information resulting from scientific documentation efforts on thermophysical properties is disseminated partly through the formal publication entitled "Thermophysical Properties Research Literature Retrieval Guide" and its supplements.

The Basic Edition of the Retrieval Guide which covers the publication years up to 1964 was published in 1967 and contains the resulting information from the first 33,700 research documents. Its full reference citation is as follows:

> Thermophysical Properties Research Literature Retrieval Guide, Touloukian, Y.S. (Editor), Gerritsen, J.K. (Technical Editor), and Moore, N.Y. (Coordinating Editor), Basic Edition, Books 1 to 3, Plenum Press, New York, 2936 pp., 1967.

This basic edition provides a quick access to the world literature on thermophysical properties published from 1822 to June 1964. It contains 139,305 codification entries on thirteen thermophysical properties of 45,116 materials, citing 33,700 references representing 26,562 authors and 3,600 scientific and technical journals and governmental and industrial report sources.

The information on thermophysical properties resulting from the research documents with accession numbers from 33,701 up to 60,000 is contained in the Retrieval Guide Supplement I which was published in early October 1973. Its full reference citation is as follows:

> Thermophysical Properties Research Literature Retrieval Guide, Supplement I (1964-1970), Touloukian, Y.S. (Editor), Gerritsen, J.K. (Technical Editor), and Shafer, W.H. (Managing Editor), Volumes 1 to 6, IFI/Plenum Data Corp., New York, 2225 pp., 1973.

This six-volume Retrieval Guide Supplement I contains 87,050 codification entries on sixteen thermophysical properties of 16,745 materials, citing 26,300 references published from mid-1964 to December 1970. An additional 9,000 synonyms and trade names are cross-referenced to assist the user in identifying the materials of interest. Supplement I follows essentially the same format of presentation as the Basic Edition. However, it has been restructured for improved user convenience in that the six volumes are actually six independent Retrieval Guides, each of which is for a specific group of materials. As a result, each user group can purchase, at a reasonable cost, selected volumes of specific interest, as well as the complete six-volume set. Since the publication of the Retrieval Guide Supplement I in 1973, much additional information on thermophysical properties has been accumulated.

Table 6 shows the statistical data on thermophysical properties information from the world literature covered by TEPIAC, listing the number of materials in each material group, the number of codification entries for each thermophysical property, and the total numbers in our computerized bibliographic information storage and retrieval system as of 31 December 1979.

The information on electronic properties resulting from scientific documentation efforts on research documents with accession numbers up to 49,400 has been published in the "Electronic Properties of Materials: A Guide to the Literature," Volumes 1 (1681 pp., 1965), Volume 2 (1799 pp., 1967), Volume 3 (1917 pp., 1971), and Update (2980 pp., 1972). Since 1973, information on electronic properties has been accumulated from 27,024 additional research documents coded for the new computerized bibliographic information storage and retrieval system. Table 7 shows similarly the statistical data on electronic properties information from the world literature covered by TEPIAC as of 31 December 1979. The number of codification entries given in Table 7 does not include those from the 49,300 research documents with accession numbers 101[a] to 49,400 processed before 1973.

The six-volume Supplement II to the "Thermophysical Properties Research Literature Retrieval Guide" was just published in December 1979. The full reference citation for the Supplement II is as follows:

> Thermophysical Properties Research Literature Retrieval Guide, Supplement II (1971-1977), Gerritsen, J.K., Ramdas, V., and Putnam, T.M. (Editors), Volumes 1 to 6, IFI/Plenum Data Co., New York, 1493 pp., 1979.

This six-volume Retrieval Guide Supplement II contains 57,108 codification entries on 14 thermophysical properties of 11,789 materials, citing 18,557

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[a] Accession numbers 1 to 100 have not been assigned to any documents.

TABLE 6. STATISTICAL DATA ON THERMOPHYSICAL PROPERTIES COVERAGE OF THE WORLD LITERATURE[a]

Material Group[b]	No. of Materials as of 31 Dec. 1979
Elements and compounds	12,821
Ferrous alloys	2,901
Nonferrous alloys	7,662
Mixtures and solutions	4,215
Systems and composites	2,820
Polymers, rubbers, etc.	737
Refractories, slags, glasses, and ceramics	2,055
Natural products	1,055
Minerals	1,053
Applied Coatings	2,874
Cermets	700
Others	848
Total	39,741

Property	No. of Codification Entries as of 31 Dec. 1979
Thermal conductivity (including accommodation coefficient and thermal contact resistance)	77,105
Specific heat	65,972
Viscosity	48,212
Thermal radiative properties	48,470
Diffusion coefficient (to 1972)	28,780
Thermal diffusivity	6,752
Prandtl number	1,408
Thermal linear and volumetric expansion	25,635
Others	14,182
Total	316,516

Number of Documents Coded for Retrieval	77,058
Number of Document Sources	8,630

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[a] Systematic coverage retrospective to the year 1920 with earlier publications as far back as to the year 1822.

[b] These material groups are the same for both thermophysical and electronic properties.

TABLE 7. STATISTICAL DATA ON ELECTRONIC PROPERTIES COVERAGE OF THE WORLD LITERATURE[a]

Material Group[b]	No. of Materials as of 31 Dec. 1979
Elements and compounds	12,821
Ferrous alloys	2,901
Nonferrous alloys	7,662
Mixtures and solutions	4,215
Systems and composites	2,820
Polymers, rubbers, etc.	737
Refractories, slags, glasses, and ceramics	2,055
Natural products	1,055
Minerals	1,053
Applied Coatings	2,874
Cermets	700
Others	848
Total	39,741

Property	No. of Codification Entries as of 31 Dec. 1979[c]
Absorption coefficient	8,629
Dielectric constant	4,744
Dielectric strength	864
Energy bands	2,344
Effective mass	1,409
Energy gap	5,574
Electric hysteresis	393
Energy levels	6,240
Electron emission properties	2,648
Electrical resistivity	39,925
Magnetoelectric properties	2,278
Hall coefficient	2,902
Luminescence properties	3,613
Magnetic hysteresis	2,670
Mobility	3,214
Magnetomechanical properties	976
Magnetic susceptibility	7,292
Photoelectronic properties	2,053
Refractive index	5,918
Thermoelectric properties	7,464
Work function	1,839
Piezoelectric properties	580
Total	113,569

Number of Documents Coded for the New Retrieval System	27,024[c]
Number of Document Sources	8,630

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[a] Systematic coverage retrospective to the year 1950 with earlier publications as far back as to the year 1853.

[b] These material groups are the same for both thermophysical and electronic properties.

[c] Does not include 49,300 documents processed before 1973.

references with accession numbers up to 94,260 and with publication years to 1977. Table 8 gives the title, number of pages, and number of reference citations for each of the six volumes of Supplement II.

The four-volume Basic CINDAS Edition of the "Electronic Properties Research Literature Retrieval Guide," which covers the accumulated information since 1973, was just published in November 1979. The full reference citation for this publication is as follows:

> Electronic Properties Research Literature Retrieval Guide, Basic CINDAS Edition (1972-1976), Chaney, J.F. and Putnam, T.M. (Editors), Volumes 1 to 4, IFI/Plenum Data Co., New York, 1604 pp., 1979.

This four-volume Retrieval Guide Basic CINDAS Edition contains 110,582 codification entries on 22 electronic, electrical, magnetic, and optical properties of 9,634 materials, citing 21,808 references with accession numbers up to 103,608 and with publication years to 1976. Table 9 gives the title, number of pages, and number of reference citations for each of the four volumes of the Basic CINDAS Edition.

TABLE 8. THERMOPHYSICAL PROPERTIES RESEARCH LITERATURE RETRIEVAL GUIDE, SUPPLEMENT II

(Covering the publication years 1971-1977)

		No. of Pages	No. of Reference Citations
Volume 1.	Elements and Inorganic Compounds	508	8345
Volume 2.	Organic Compounds and Polymeric Materials	188	1917
Volume 3.	Alloys, Intermetallic Compounds, and Cermets	285	2703
Volume 4.	Oxide Mixtures and Minerals	162	1651
Volume 5.	Mixtures and Solutions	160	1571
Volume 6.	Coatings, Systems, and Composites	190	2370
		1493	18557

TABLE 9. ELECTRONIC PROPERTIES RESEARCH LITERATURE RETRIEVAL GUIDE, BASIC CINDAS EDITION

(Covering the publication years 1972-1976)

		No. of Pages	No. of Reference Citations
Volume 1.	Elements	502	8021
Volume 2.	Inorganic and Intermetallic Compounds	621	8750
Volume 3.	Alloys and Cermets	262	2839
Volume 4.	Mixtures, Rocks and Minerals, Composites and Systems, Polymers	219	2198
		1604	21808

SECTION III

DATA TABLES ACTIVITIES

1. DATA EXTRACTION AND COMPILATION

As a result of the systematic and comprehensive search of literature in the scientific documentation phase of this program described earlier, the original research documents of interest to TEPIAC are uncovered. These documents are procured and studied, from which the data are extracted, scrutinized, organized, converted to be in uniform units, and homogeneously plotted and tabulated in the form of "Tables of Original Data" which present all the available experimental data and information, as the first stage toward the preparation of internally consistent tables of critically evaluated "best data" referred to as "Tables of Recommended Reference Values." Subsequently, this information is reviewed and the organized data are given a final critical evaluation. At this second stage, the experimental data are analyzed, correlated, and synthesized, and the recommended values are generated. This two-stage data processing is found by TEPIAC to be the most logical approach lending itself to greater effectiveness in bringing to the user the results of this type of painstaking research in the shortest possible time.

The detailed procedures which TEPIAC follows in data compilation as well as in data analysis and synthesis are not necessarily a matter of established routines and do vary from property to property and from one group of materials to another. There are certain principles which must be followed, however, irrespective of the type of data or materials involved. For example: (a) the data should be extracted directly from their original sources to ensure freedom from errors of transcription; (b) the characterization and physical and chemical conditions of the test specimen should be specified as clearly as possible so as to fully identify the materials tested; (c) especially for solids, the source of the material, method of fabrication, thermal history, heat, mechanical, irradiative, and other treatments of the specimen and the measuring method and conditions should be noted; (d) if a comparative measurement method is used, the material used as comparative standard and its property values should be cited; (e) the accuracy and precision of the data reported should be separately denoted; (f) the complete reference to the original work should always be cited with the data; etc. Whenever some of the above criteria cannot be satisfied because of absence of necessary information in the original work, an attempt is made to contact the author, if possible. In the cases where data cannot be adequately evaluated by TEPIAC due to lack of required information, such data are appropriately "flagged".

In connection with its activities in data processing, TEPIAC has established, through experience, appropriate procedures of operational practice which lend to good organization of work, uniform recording and filing, and other procedures of "good housekeeping," thus assuring ready tractability of original records of processed data, which are permanent working records for reference at any time in the future. Every effort has been made and all necessary steps have been taken to ensure that the data tables production rate is the maximum possible consistent with TEPIAC's high professional standards.

Within each data tables project there are four major tasks: (a) data extraction and compilation, (b) data evaluation, analysis, synthesis, and generation of recommended reference values, (c) text preparation, and (d) preparation of a manuscript for publication.

The statistical summary of accomplishments of the task on data extraction and compilation for all material properties are presented in Table 10, which shows that in this 12-month reporting period 2,148 research documents have been processed for data extraction, yielding 842 data source references, and 2,675 data sets have been compiled. These make a grand total of 44,855 research documents processed for data extraction, yielding 20,496 data source references, and TEPIAC has compiled a total of 93,713 data sets in its data file. It is important to note that data extraction and compilation is only one of the tasks and a small part of the total efforts.

TABLE 10. STATISTICAL SUMMARY OF ACCOMPLISHMENTS OF DATA EXTRACTION AND COMPILATION

	Total as of 31 Dec. 1978	This Period	Total as of 31 Dec. 1979
No. of documents processed	42,707	2,148	44,855
No. of documents accepted as data sources	19,654	842	20,496
No. of materials compiled	10,599	128	10,727
No. of data sets compiled	91,038	2,675	93,713

In many of the research documents data are presented in graphs only. More than ten years in the past a Gerber Electronic Digitizer had been used at TEPIAC to read data points off graphs. Recently the Gerber Digitizer has been replaced by a higher speed and more versatile Talos Electronic Digitizer/DEC Minicomputer-Data Processor for performing digitizing and more advanced data processing. The new equipment, which was purchased by funds provided by Purdue University, is in full operation. Whenever the graph is too small to give accurate readings, an attempt is made to contact the author for original data in tabular form.

2. DATA EVALUATION, CORRELATION, ANALYSIS, SYNTHESIS, AND GENERATION OF RECOMMENDED VALUES

Owing to the difficulties encountered in the accurate measurement of the properties of materials and in the adequate characterization of test specimens, especially solids, the property data recorded in the scientific and technical literature are often conflicting, widely diverging, and subject to large uncertainty. Indiscriminate use of literature data for engineering and design calculations without knowing their reliability is dangerous and may cause inefficiency or product failure, which at times can be disastrous. Consequently, only critically evaluated data should ever be used. Another important TEPIAC task is, therefore, to critically evaluate and analyze the available data and information, to give judgment on the reliability and accuracy of the data, and to generate recommended values.

The procedure involves critical evaluation of the validity of the data and related information, resolution and reconciliation of disagreements in conflicting data, correlation of data in terms of various controlling parameters, curve fitting with theoretical or empirical equations, comparison of results with theoretical predictions or with results derived from theoretical relationships or from generalized empirical correlations, etc. Besides critical evaluation and analysis of existing data, theoretical methods and semiempirical techniques are employed to fill data gaps and to synthesize fragmentary data so that the resulting recommended values are internally consistent and cover as wide a range of each of the controlling parameters as possible.

Considering the thermal conductivity data for example, in the critical evaluation of the validity and reliability of a particular set of experimental data, the temperature dependence of the data is examined and any unusual dependence or anomaly is carefully investigated. The experimental technique is reviewed to see whether the actual boundary conditions in the measurement agreed with those assumed in the theoretical model used to define the property. It is ascertained whether all the stray heat flows and losses were prevented or minimized and accounted for. Furthermore, the reduction of data is examined to see whether all the necessary corrections were appropriately applied, and the estimation of uncertainties is checked to ensure that all the possible sources of errors, particularly systematic errors, were considered by the authors. Since the primary factor contributing to unreliable and erroneous experimental results is the systematic error in the measurement, experimental data can be judged to be reliable only if all sources of systematic error have been eliminated or minimized and accounted for. Major sources of systematic error may include unsuitable experimental method, poor experimental technique, poor instrumentation and poor sensitivity of measuring devices, sensors, or circuits, specimen and/or thermocouple contamination, unaccounted for stray heat flows, incorrect form factor, and, perhaps most important, the mismatch between actual experimental boundary conditions and those assumed in the theoretical model used to derive the value of thermal conductivity. These and other possible sources of errors are carefully considered in critical evaluation of experimental data. The uncertainty of a set of data depends, however, not only on the estimated error of the data but also on the adequacy of characterization of the material for which the data are reported.

Besides evaluating and analyzing individual data sets, correlation of data in terms of various controlling parameters is a valuable technique that is frequently used in data analysis. These parameters may include purity, composition, residual electrical resistivity or electrical resistivity ratio (if a metal), density or porosity, hardness, crystal axis orientation, degree of cold working, degree of heat treatment, etc. Applying the principle of corresponding states, reduced property values may be correlated with reduced temperature, pressure, and other reduced parameters.

Several properties of the same material can also be cross-correlated. For instance, thermal conductivity, specific heat, and density can be correlated with thermal diffusivity, and viscosity and specific heat of a gas can be correlated with thermal conductivity through the Chapman-Enskog theory or through the experimental data on the Prandtl number. For a fluid, the property of the saturated liquid can also be correlated with that of the saturated vapor.

It is important to note that irrespective of how much experimental data are available, reliable information exists only after the experimental data had been critically evaluated and recommended values generated. Figures 2 to 21 serve to illustrate this point. Figure 2 presents the experimental data and the recommended values on the thermal conductivity of titanium carbide and shows that the lower two sets of experimental data are utterly erroneous, being about five times too low at 800 K and ten times too low at 1350 K. Yet the lower two sets of data were published by an internationally well-known scientist and were obtained by using two completely different experimental methods for measurement. Titanium carbide has been extensively used to make machine tools. If machine tool designers blindly use the lower data for design without knowing that the data are erroneous, one can imagine the serious consequence.

Figure 3 presents the experimental data and the recommended values on the thermal conductivity of platinum (60%) + rhodium (40%) alloy. This figure shows that the higher experimental data are utterly erroneous, being about 140% too high at 550 K.

Figure 4 presents the experimental data and the recommended values on the thermal conductivity of tungsten and shows that most of the experimental data are erroneous, conflicting, and widely diverging. It has been estimated that the cost of experimental research (around 1968) was about $30,000 per published research paper. Since the number of published papers reporting experimental results on the thermal conductivity of tungsten is larger than 100, a total of over $3,000,000 research funds had been spent to produce the confusion of experimental data shown in Figure 4. It can apparently be seen from Figure 4 that it was not until TEPIAC critically evaluated the discordant experimental data and generated the recommended reference values that the true values of the thermal conductivity of tungsten were known.

Figure 5 presents the experimental data and the recommended values on the thermal diffusivity of tungsten. It shows that the lower three sets of data are utterly erroneous, being about five times too low. The recommended curve shown in the figure generated by TEPIAC not only indicates where the true thermal diffusivity values of tungsten are but also gives the values covering the full range of temperature, going far beyond the limited range covered by the experimental data.

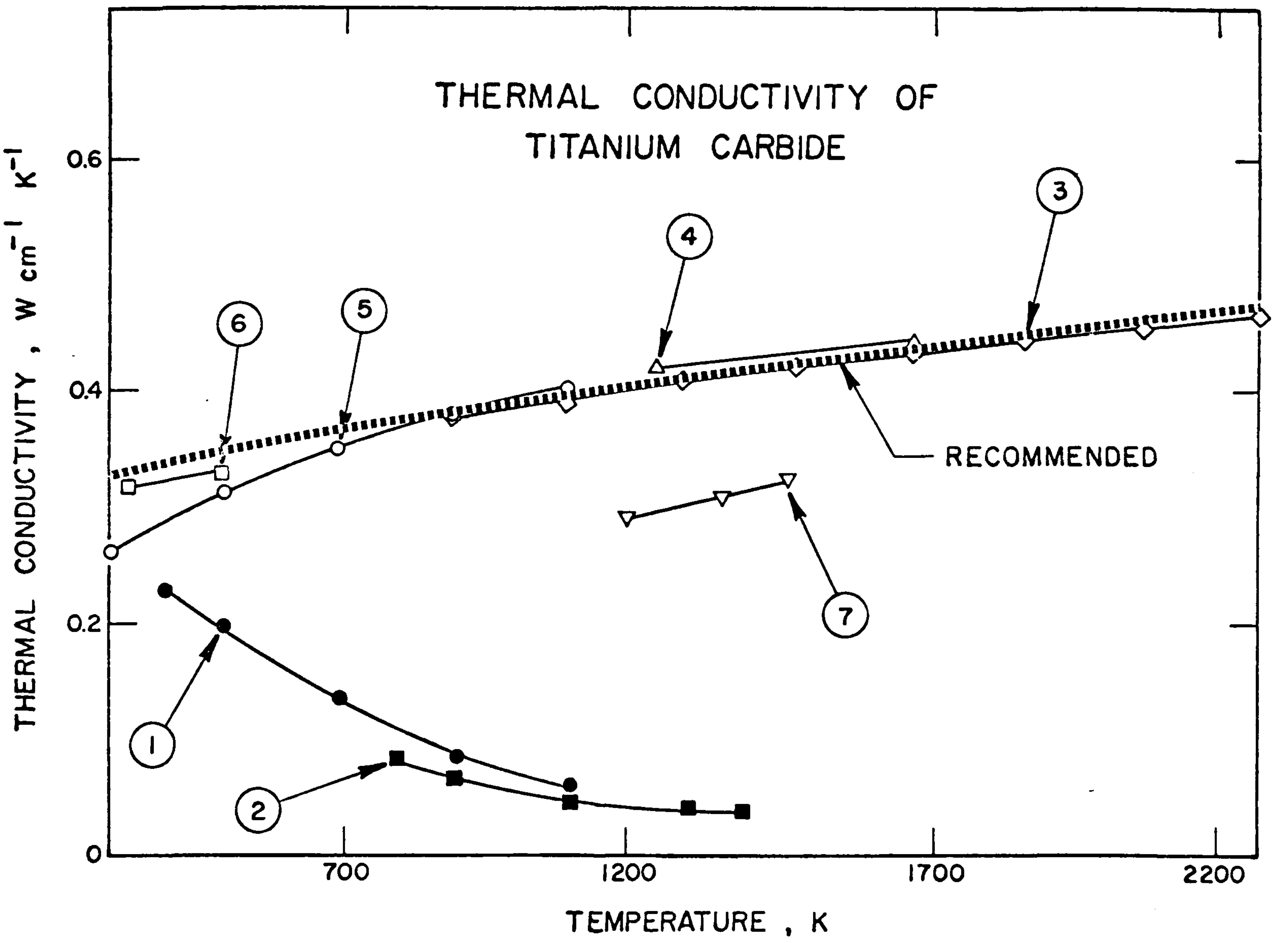

Figure 2. Experimental data and recommended values on the thermal conductivity of titanium carbide. This shows that the lower experimental data are utterly erroneous, being about five times too low at 800 K and ten times too low at 1350 K.

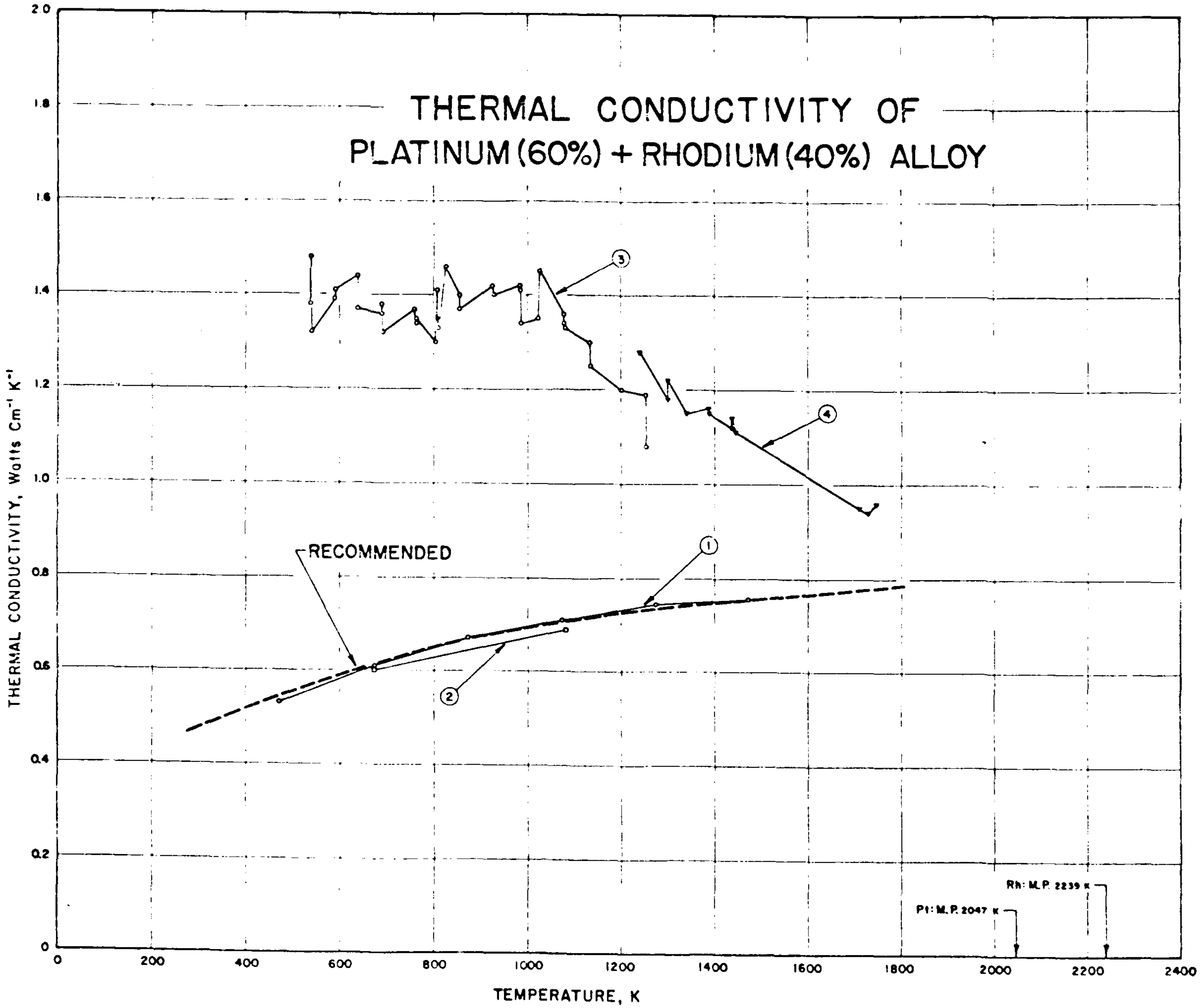

Figure 3. Experimental data and recommended values on the thermal conductivity of platinum (60%) + rhodium (40%) alloy. This shows that the higher experimental data are utterly erroneous, being about 140% too high at 550 K.

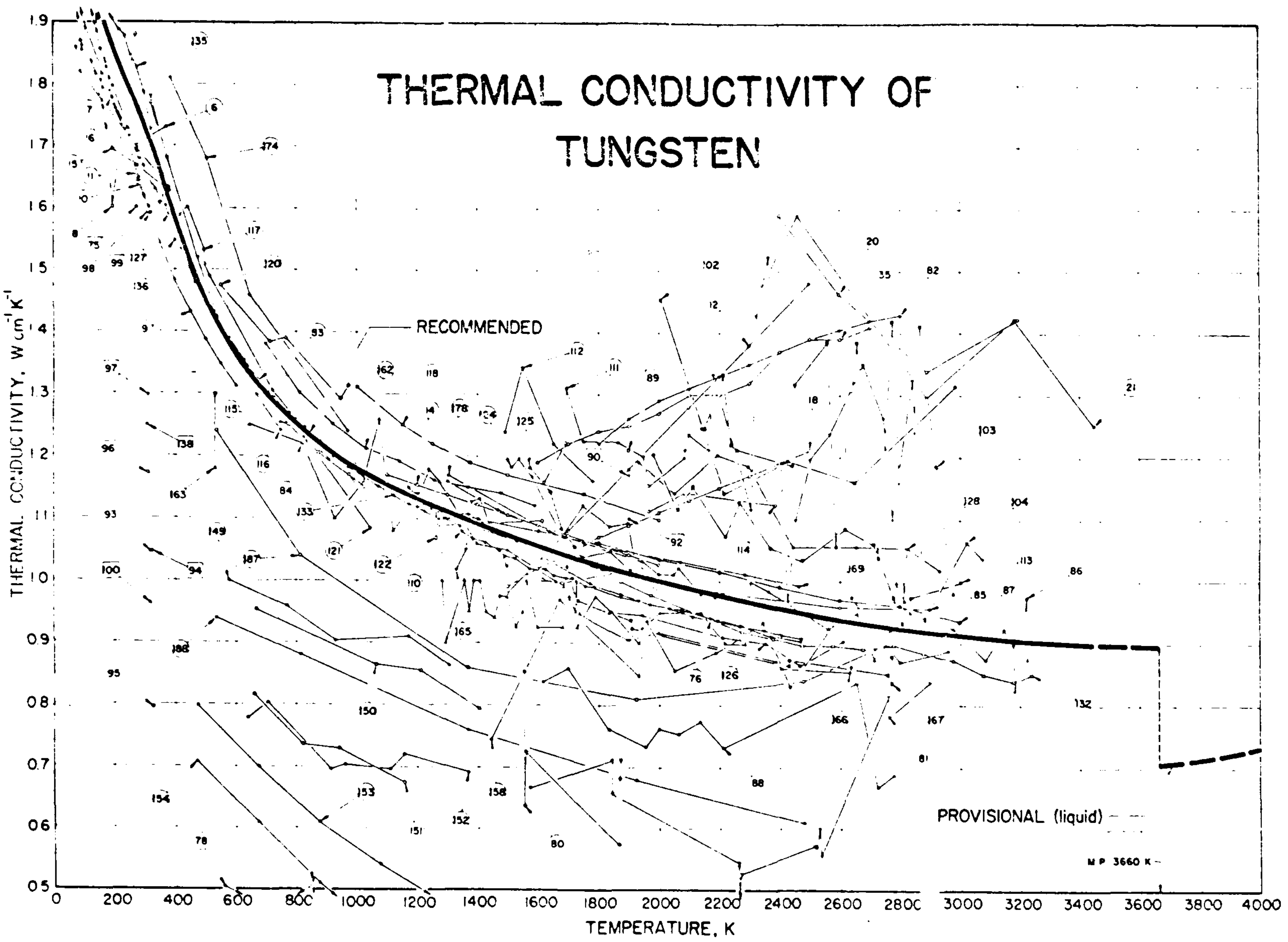

Figure 4. Experimental data and recommended values on the thermal conductivity of tungsten. This shows that most of the experimental data are erroneous, conflicting, and widely diverging.

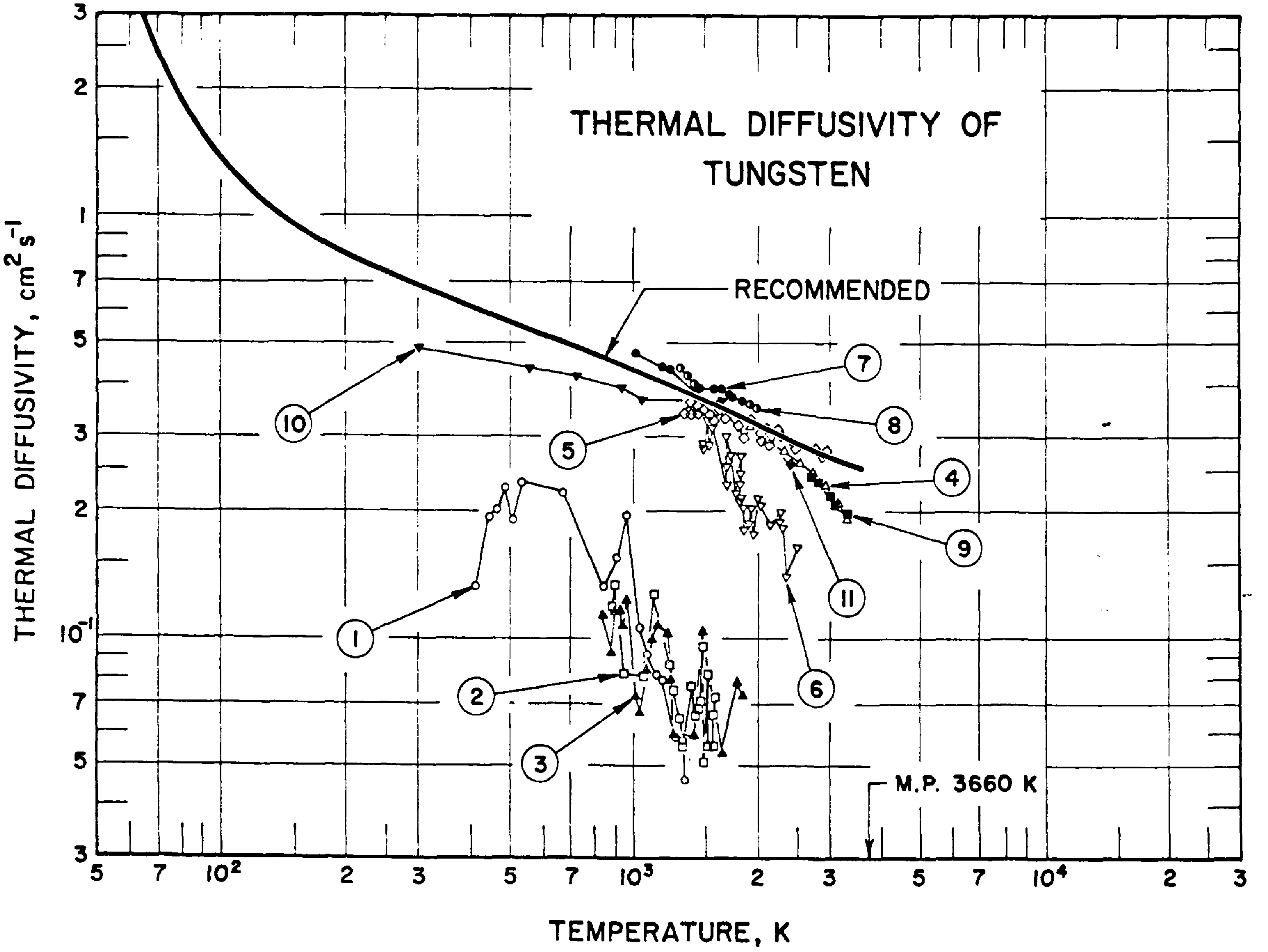

Figure 5. Experimental data and recommended values on the thermal diffusivity of tungsten. This shows that the lower experimental data are utterly erroneous, being about five times too low.

Figure 6 presents all the available experimental data on the thermal conductivity of aluminum + copper alloys, which are very limited, fragmentary, and conflicting. Through data evaluation, analysis, synthesis, and semi-theoretical calculations based on some of the data selected from those shown in Figure 6 and on the available data on the electrical resistivity, recommended values were generated which cover a full range of temperature and alloy composition as presented in Figure 7.

Figure 8 shows all the available experimental data on the absolute thermoelectric power of nickel + copper alloys, which are likewise very limited, fragmentary, and conflicting. Figure 9 presents the recommended values for the absolute thermoelectric power of nickel + copper alloys covering a full range of temperature and alloy composition, which were generated through critical evaluation, correlation, analysis, and synthesis of the limited experimental data shown in Figure 8.

The refractive index (n) of alkali halides has received few measurements. Of the twenty alkali halides, sufficient data are available for only six. On a number of them only one single measurement has been made. The available information is even less for its temperature derivative (dn/dT) and wavelength derivative (dn/dλ). Only seven of the twenty alkali halides have received attention and no measurement has ever been made on thirteen of them. However, by using theoretical and semi-empirical techniques ingenuously in data analysis and synthesis, we were able to generate the refractive index and its temperature and wavelength derivatives for all the twenty alkali halides over the full wavelength range. Figure 10 shows the two experimental data points (the lower one of which is far off) available for the refractive index of lithium chloride and our recommended and provisional values which cover the full range of wavelength. No experimental data on the temperature and wavelength derivatives of the refractive index of lithium chloride are available, however we were able to generate predicted values for both of these two derivatives covering the full range of wavelength through correlation, prediction, and semi-theoretical calculation. Similar work has been done for the other alkali halides. In so doing we have generated recommended or predicted values for the refractive index, its temperature derivative, and its wavelength derivative of all the twenty alkali halides, which are shown respectively in Figures 11, 12, and 13.

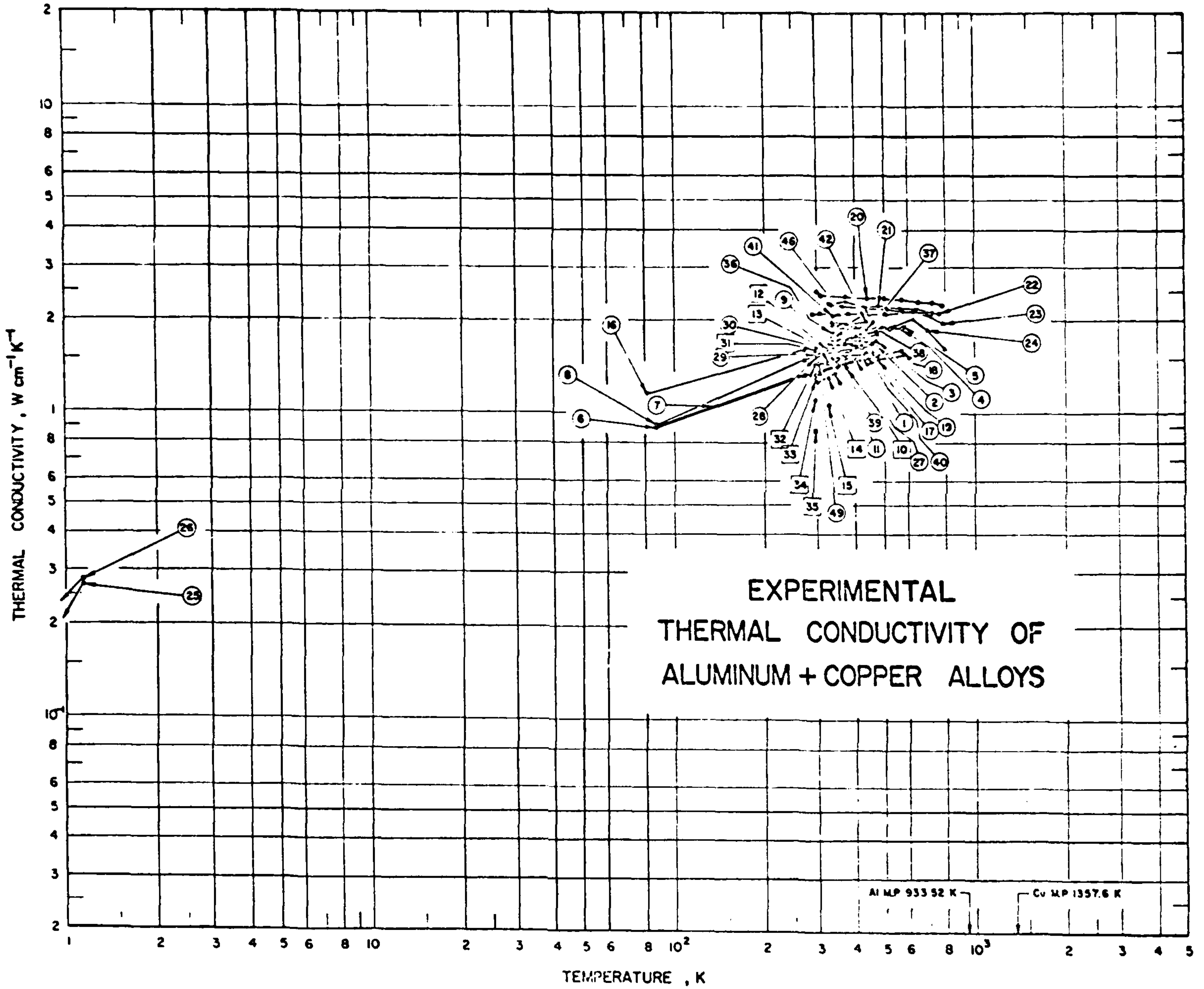

Figure 6. Experimental data on the thermal conductivity of aluminum + copper alloys. These experimental raw data are very limited, fragmentary, and conflicting.

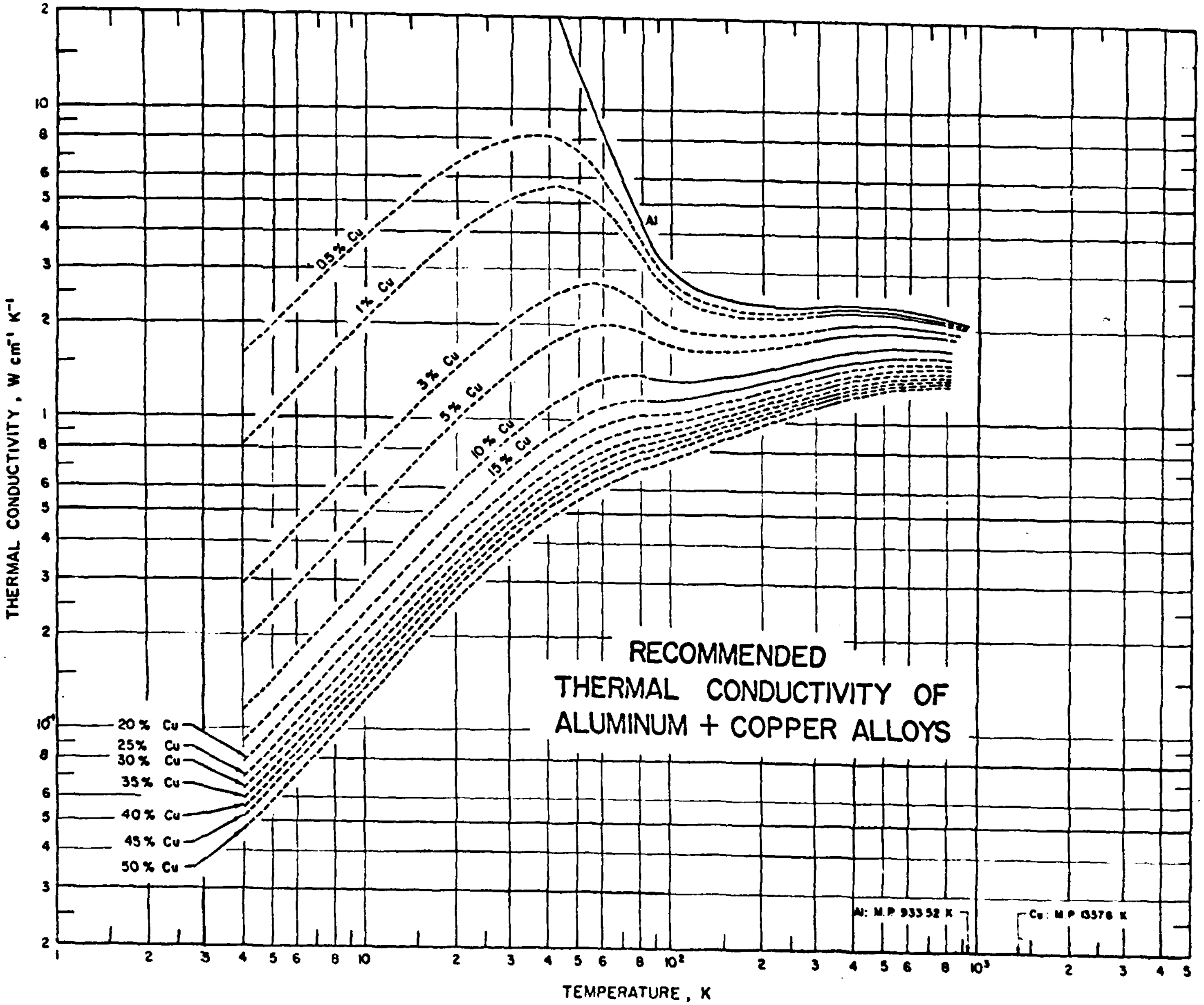

Figure 7. Recommended values for the thermal conductivity of aluminum + copper alloys. These recommended values are generated through data evaluation, analysis, synthesis, and semi-theoretical calculations based on the very limited experimental raw data shown in Figure 6 and on the available data on the electrical resistivity.

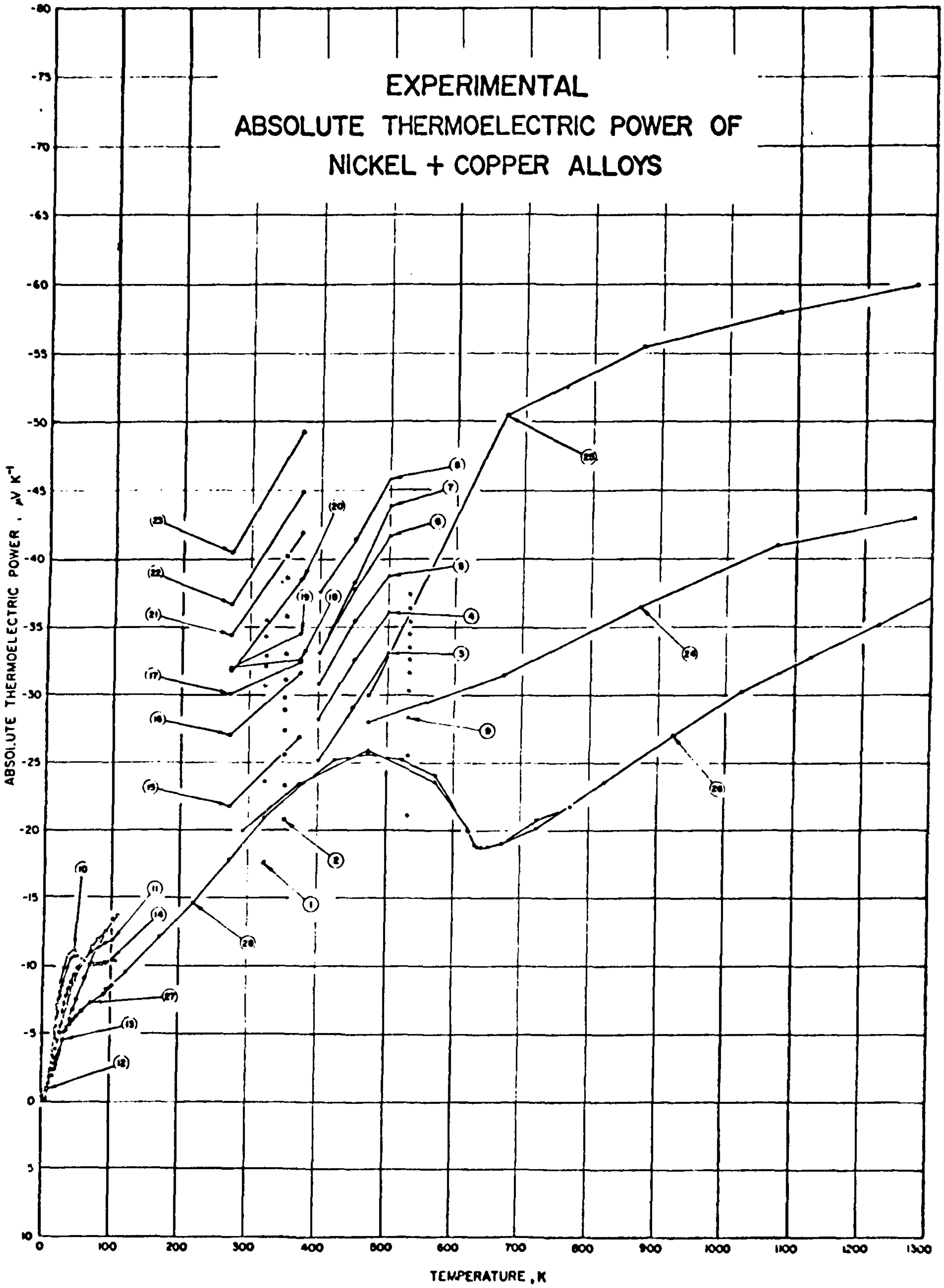

Figure 8. Experimental data on the absolute thermoelectric power of nickel+copper alloys. These experimental raw data are very limited, fragmentary, and conflicting.

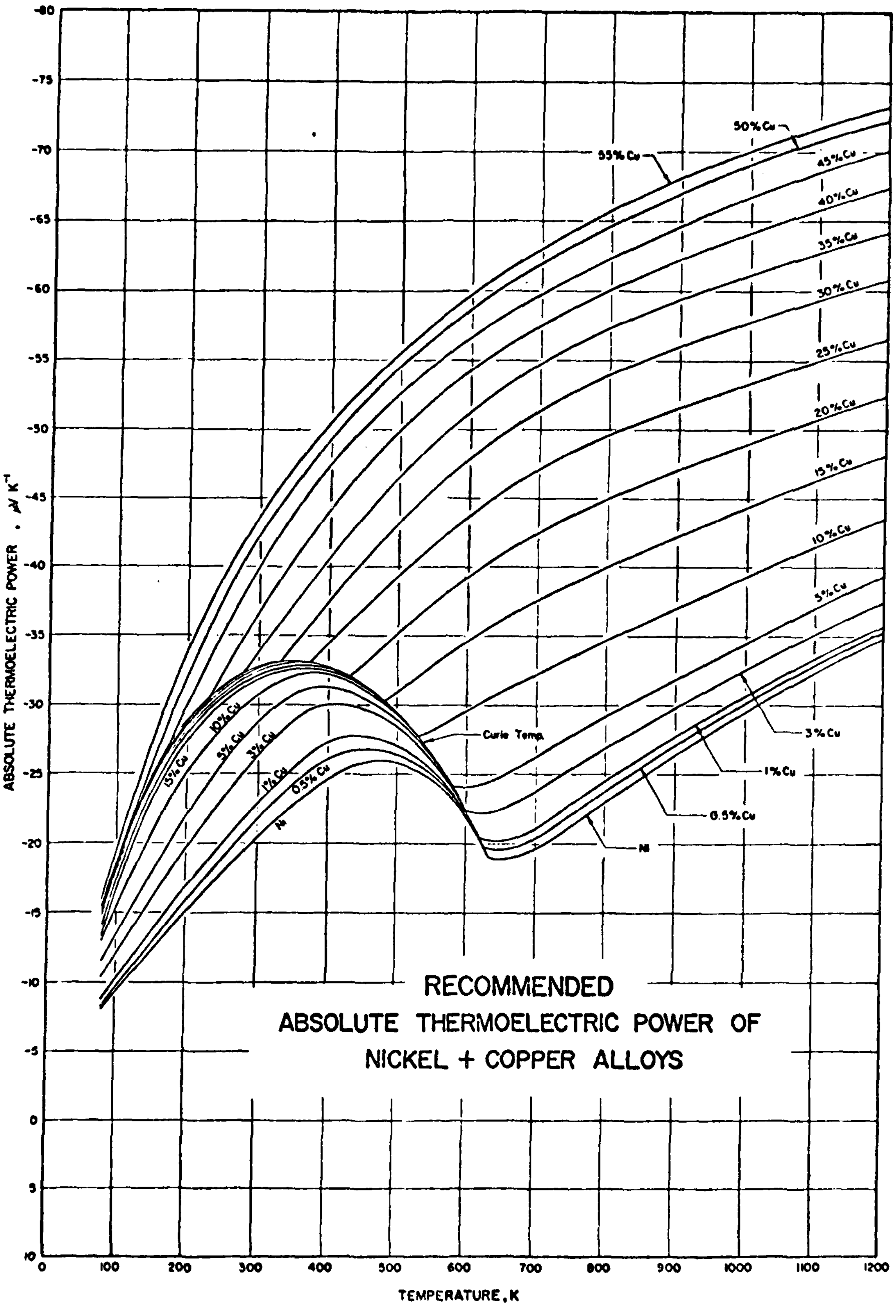

Figure 9. Recommended values for the absolute thermoelectric power of nickel+copper alloys. These recommended values are generated through data evaluation, correlation, analysis, and synthesis from the very limited experimental raw data shown in Figure 8.

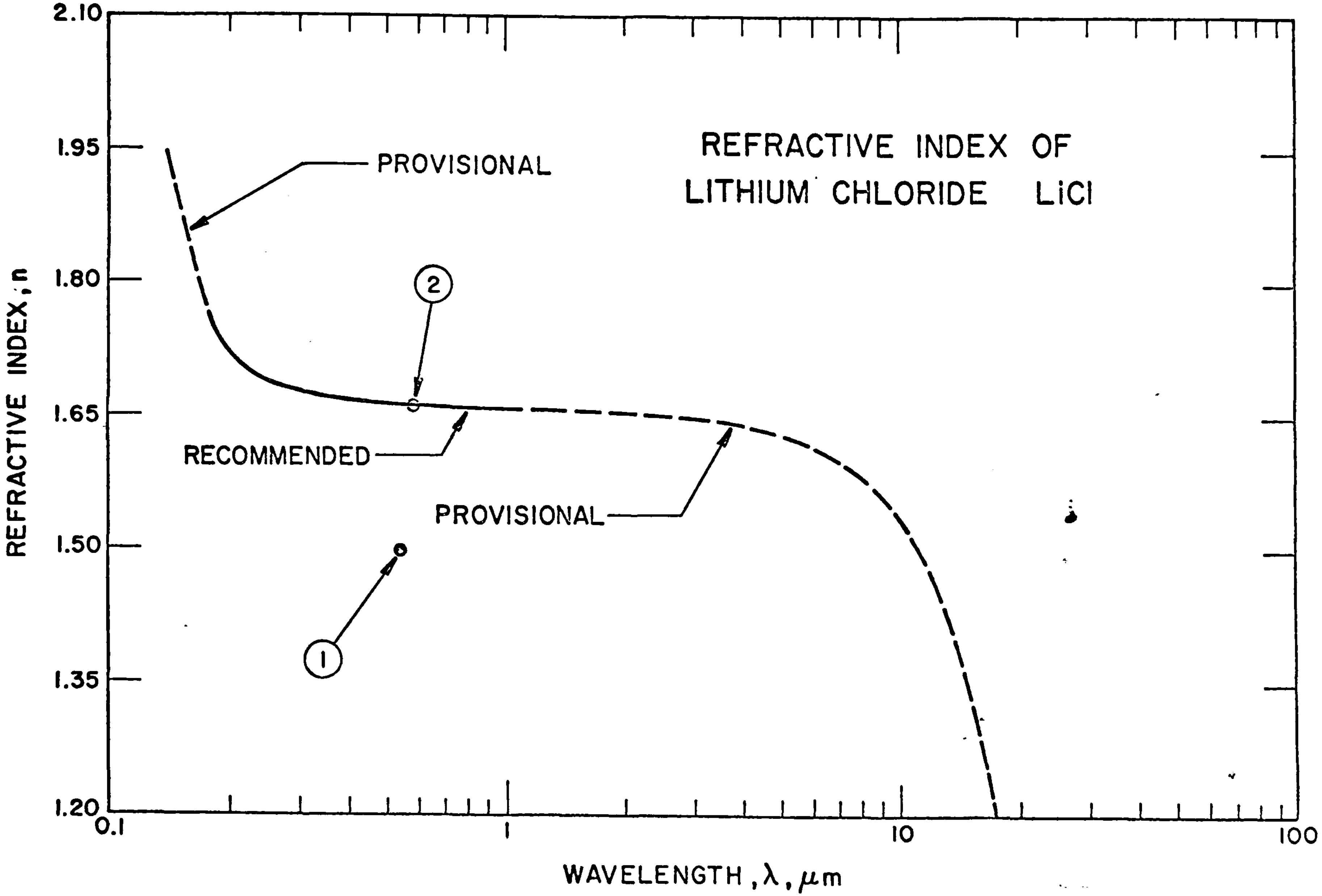

Figure 10. Experimental data and recommended and provisional values on the refractive index of lithium chloride. The lower experimental data point is far off. The full-range values are generated through data synthesis, correlation, and semi-theoretical calculation.

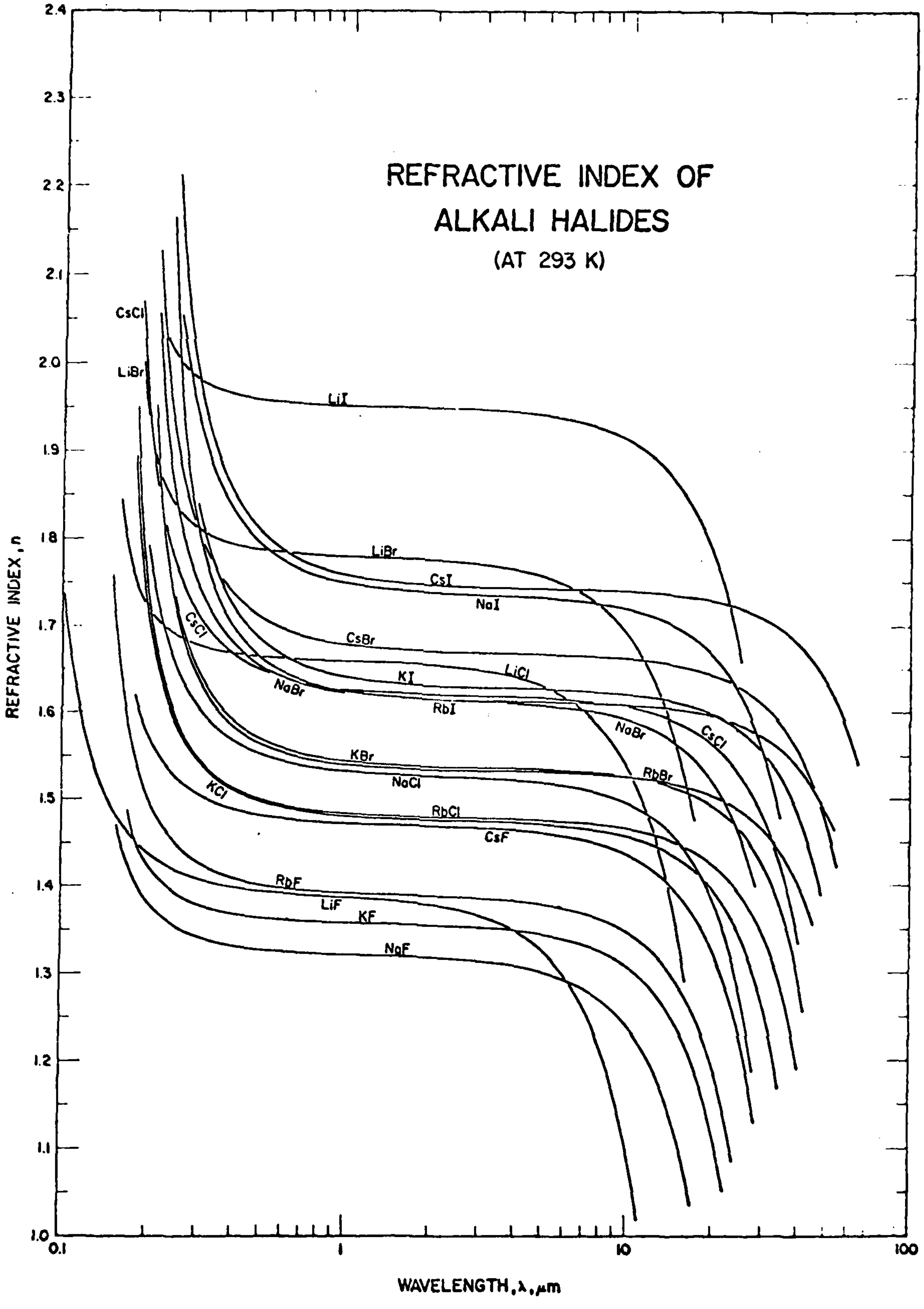

Figure 11. Recommended and provisional values for the refractive index of all twenty alkali halides. Most of the values are generated through synthesis, correlation, prediction, and calculation.

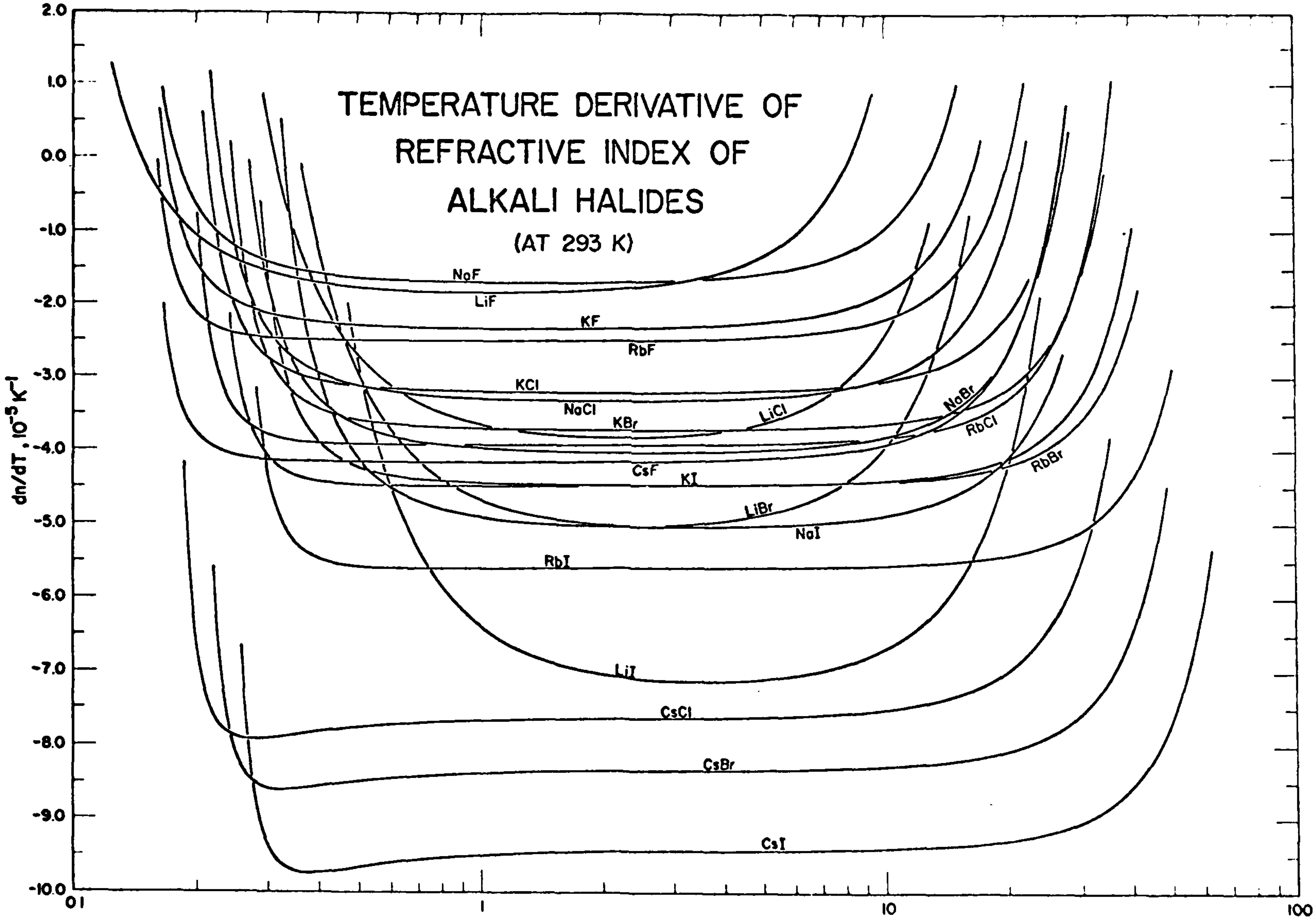

Figure 12. Recommended and provisional values for the temperature derivative of the refractive index of all twenty alkali halides. Most of the values are generated through correlation, prediction, and calculation.

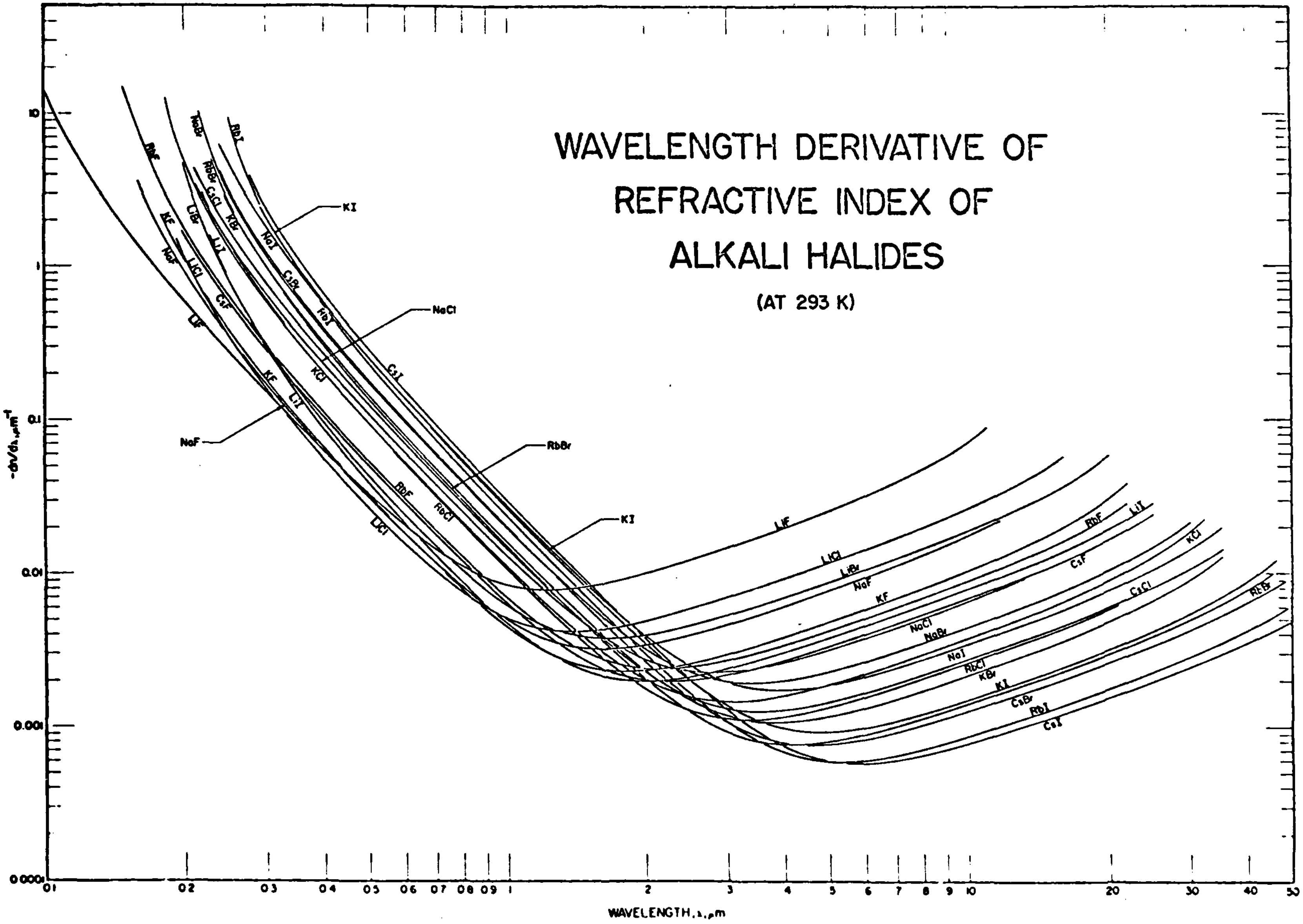

Figure 13. Provisional values for the wavelength derivative of the refractive index of all twenty alkali halides. Most of the values are calculated.

Figures 14 and 15 show all the available experimental data on the refractive index of silicon for the wavelength and temperature dependences, respectively. From these fragmentary and often conflicting data, recommended values were generated as presented in Figure 16 which cover a full range and are simultaneously as a function of both wavelength and temperature. Such a complete spectrum of values on the refractive index of silicon is for the first time ever available.

It should be apparent from the above illustrations that data evaluation, correlation, analysis, and synthesis is a very powerful tool which not only can clean up a body of conflicting and confusing data, but also can create new knowledge, which in itself is a major contribution to science and technology. Thus, TEPIAC can provide to the user not only just any (or all) available data and information (which is usually the limit that an ordinary information center can do), but the evaluated correct data and information, and furthermore, in many cases TEPIAC can provide predicted data and information to the user even when the required data and information are completely lacking and nonexisting. This is why TEPIAC has traditionally always stressed data evaluation, analysis, and synthesis and the generation of reference data.

3. HANDBOOKS AND DATA BOOKS[a]

The phenomenal growth of science and technology in recent decades has brought about a universal appreciation of the fact that the availability of adequate reference data for various properties of materials is essential to national progress, economy, and defense. To this end, TEPIAC has been contributing greatly through the generation of reference data tables and the design, preparation, publication, and maintenance of data books and handbooks, which is the principal means of satisfying user requirements for comprehensive and authoritative data and information on material properties.

The monumental 14-volume 16,810-page Thermophysical Properties of Matter - The TPRC Data Series has been completed and a summary of statistical data on the entire Data Series is presented in Table 11. For the user convenience and for promoting the sale of the Data Series, an index volume entitled Master Index to Materials and Properties for the TPRC Data Series was prepared. This Master Index lists alphabetically all the 6362 materials contained in the 13 volumes and give the volume number and page number for each property of each of the materials listed. This index volume has been published by IFI/Plenum Data Company and copies have been available for distribution since June 1979.

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[a] The work on handbooks and data books has been jointly sponsored by DLA and other agencies and organizations.

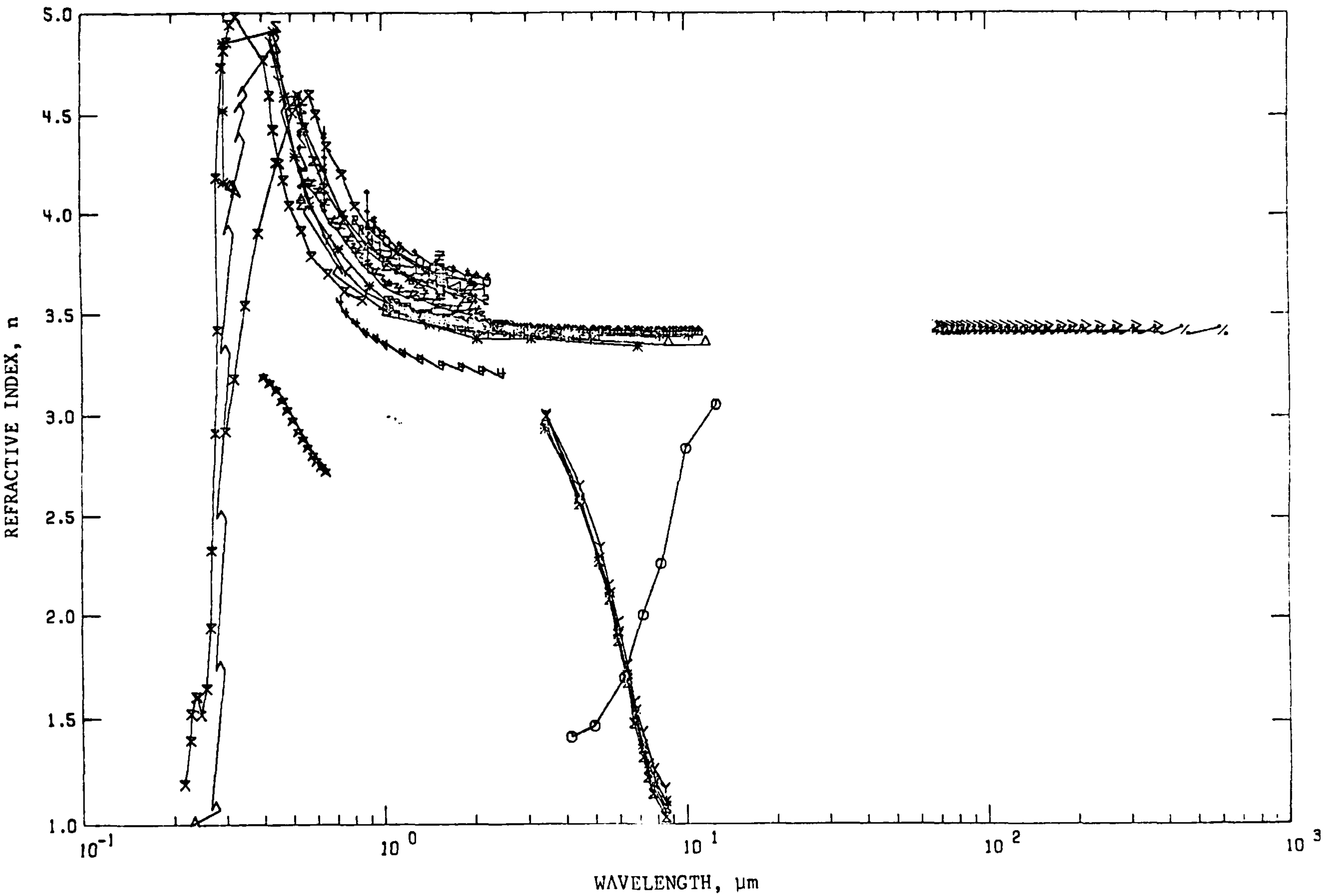

Figure 14. Experimental data on the refractive index of silicon (wavelength dependence).

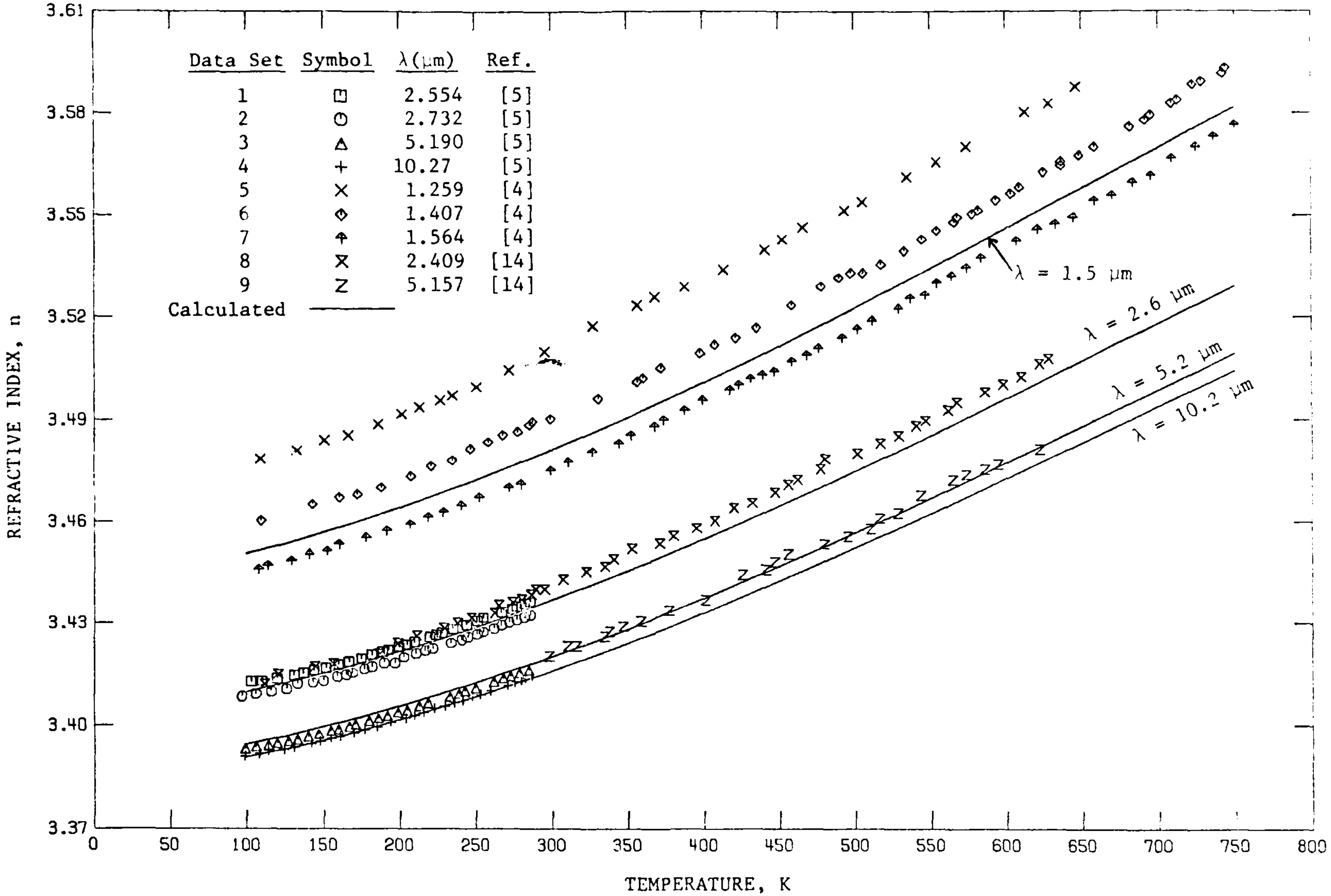

Figure 15. Experimental data on the refractive index of silicon (temperature dependence). Some calculated values are also shown for comparison.

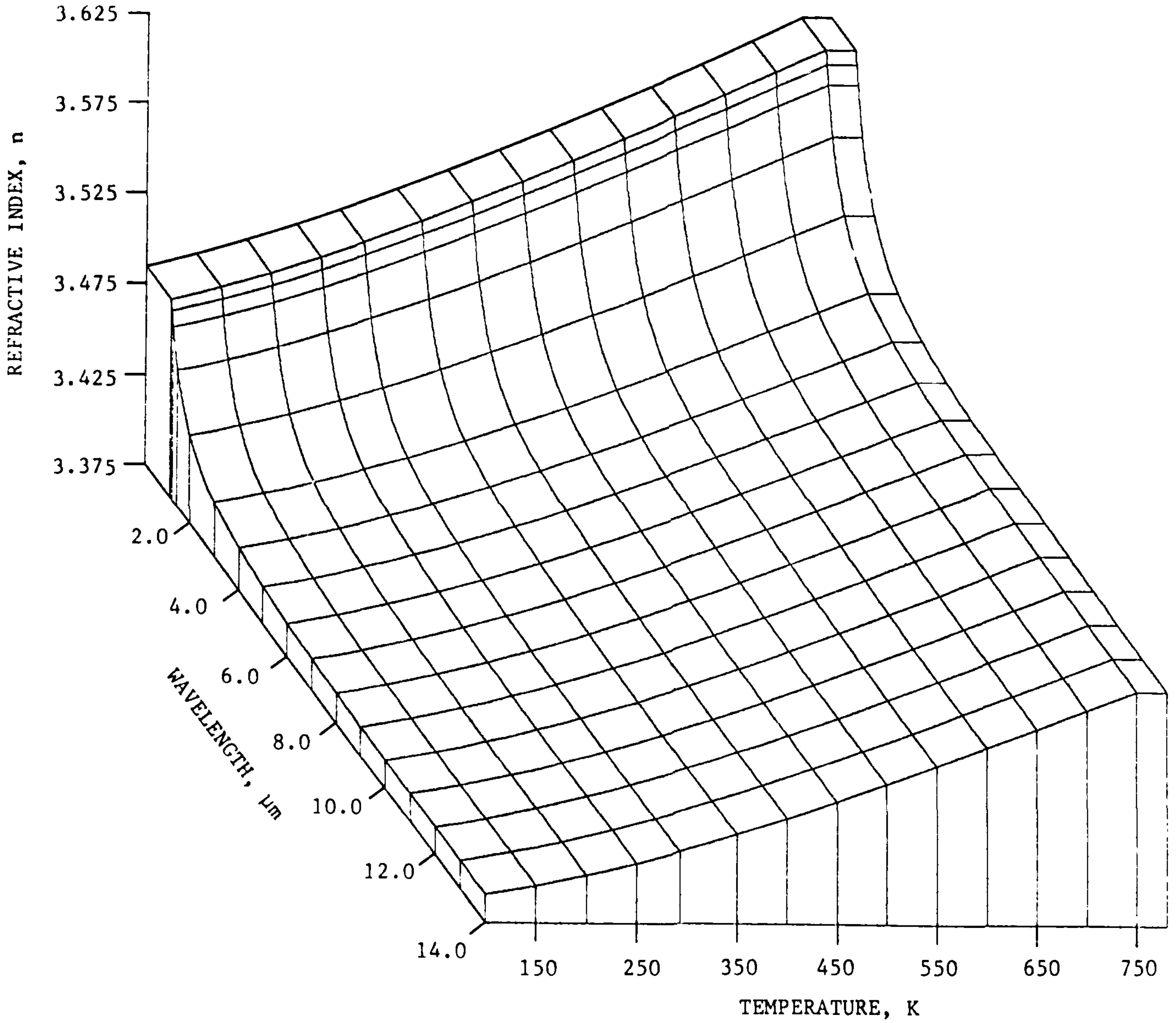

Figure 16. Recommended values for the refractive index of silicon as a function of both wavelength and temperature.

TABLE 11. SUMMARY OF STATISTICAL DATA ON "THERMOPHYSICAL PROPERTIES OF MATTER - THE TPRC DATA SERIES"

	No. of Pages	No. of Data Sets	No. of Materials	No. of References		
				To Text	To Data Sources	Total
Volume 1. Thermal Conductivity - Metallic Elements and Alloys	1595	5539	892	433	1013	1446
Volume 2. Thermal Conductivity - Nonmetallic Solids	1302	4627	812	439	598	1037
Volume 3. Thermal Conductivity - Nonmetallic Liquids and Gases	707	1505	170	681	725	1406
Volume 4. Specific Heat - Metallic Elements and Alloys	830	1186	322	61	428	789
Volume 5. Specific Heat - Nonmetallic Solids	1737	1009	550	61	457	518
Volume 6. Specific Heat - Nonmetallic Liquids and Gases	383	863	56	70	595	665
Volume 6 Supplement	169	726	307	0	878	878
Volume 7. Thermal Radiative Properties - Metallic Elements and Alloys	1644	5130	242	149	371	520
Volume 8. Thermal Radiative Properties - Nonmetallic Solids	1890	4971	782	121	455	576
Volume 9. Thermal Radiative Properties - Coatings	1569	5269	1161	180	295	475
Volume 10. Thermal Diffusivity	760	1733	445	253	315	568
Volume 11. Viscosity	801	1803	188	1218	377	1595
Volume 12. Thermal Expansion - Metallic Elements and Alloys	1440	4253	672	91	781	872
Volume 13. Thermal Expansion - Nonmetallic Solids	1786	4990	815	101	1112	1213
Index Volume. Master Index to Materials and Properties	197	----	6362	---	----	----
Total	16810	43604	----	3858	8400	12258

As the TPRC Data Series is completed, a new plan for the continuing data tables generation and publication with an even greater scope has been developed and is being implemented. In this plan, a new McGraw-Hill/CINDAS Data Series on Material Properties will be prepared and published. The structure of the new CINDAS Data Series had been revised three times since the initial conceptual presentation of it in 1977. At this time a realistic structure has been attained and it is contemplated that CINDAS Data Series will consist of some 42 volumes comprising approximately 14,000 pages. The revised structure and scope of the CINDAS Data Series is presented in Table 12. The revision of the structuring of the CINDAS Data Series has been mainly the combination of volumes previously conceived. For example, the previously conceived two volumes: one on "Non-stainless Alloy Steels" and the other on "Carbon Steels and Cast Irons" will be combined to become a larger volume entitled "Properties of Nonstainless Alloy Steels, Carbon Steels, and Cast Irons"; the completion of this new volume will actually be the completion of two volumes on alloys. The previously conceived volume on "Alloys of Hafnium, Molybdenum, Niobium, Tantalum, Titanium, Tungsten, and Zirconium" will combine with three other volumes on alloys to become a much larger volume entitled "Properties of Selected Transition-Metal Alloys," the completion of which will actually be the completion of four volumes on alloys.

Volumes in the new CINDAS Data Series will primarily be application (material) oriented, in contrast to the discipline (property) oriented structure of the old TPRC Data Series. In other words, each volume in the CINDAS Data Series will contain data on all the important physical properties of a group of materials, rather than containing data on only one property of many materials such as the volume in the old TPRC Data Series. In presenting the property data in each volume, all possible steps will be taken to reduce the buck of the presentation by limiting the reporting to essential elements of information without sacrificing the information essential for scientific and technical usage of the data reported. In other words, the volumes will comprise mainly the recommended reference values or selected data.

Table 13 shows the properties to be covered by the volumes of the new CINDAS Data Series. The properties include eleven thermophysical and seven electrical, electronic, optical, and magnetic properties which are to be presented as a function of one or more variables such as temperature, pressure,

TABLE 12. STRUCTURE AND SCOPE OF "McGRAW-HILL/CINDAS DATA SERIES ON MATERIALS PROPERTIES"

GROUP I. THEORY, ESTIMATION, AND MEASUREMENT OF PROPERTIES

Volume I-1. Transport Properties of Fluids: Thermal Conductivity, Viscosity, and Diffusion Coefficient
Volume I-2. Transport Properties of Solids: Thermal Conductivity, Electrical Resistivity, and Thermoelectric Properties
Volume I-3. Specific Heat of Solids
Volume I-4. Thermal Expansion of Solids
Volume I-5. Thermal Radiative Properties of Solids

GROUP II. PROPERTIES OF SPECIAL MATERIALS

Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases
Volume II-2. Physical Properties of Rocks and Minerals
Volume II-3. Optical Properties of Optical Materials
Volume II-4. Thermal Radiative Properties of Coatings

GROUP III. PROPERTIES OF THE ELEMENTS

Volume III-1. Properties of Selected Ferrous Alloying Elements (Cr, Co, Fe, Mn, Ni, and V)
Volume III-2. Properties of Nonmetallic Fluid Elements (Ar, Br, Cl, F, He, H_2, I, Kr, Ne, N_2, O_2, Rn, and Xe)
Volume III-3. Properties of Selected Refractory Elements (Hf, Mo, Nb, Ta, Ti, W, and Zr)
Volume III-4. Properties of Liquid Metal Elements (Li, Na, K, Rb, Cs, Fr, Hg, Ga, and In)
Volume III-5. Properties of Selected Nonferrous Alloying Elements and Precious Metals (Al, Be, Cd, Cu, Pb, Mg, Sn, Zn, Au, Ir, Pd, Pt, Re, Rh, and Ag)
Volume III-6. Properties of Rare-Earth and Radioactive Elements (Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Tc, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, and Lw)
Volume III-7. Properties of Selected Semiconducting, Semimetallic, Nonmetallic Solid, and Other Elements (Ge, Po, Se, Si, Te, Sb, As, Bi, At, B, C, P, S, Ba, Ca, Os, Ru, Sr, and Tl)

GROUP IV. PROPERTIES OF ALLOYS AND CERMETS

Volume IV-1. Properties of Stainless Steels
Volume IV-2. Properties of Nonstainless Alloy Steels, Carbon Steels, and Cast Irons
Volume IV-3. Properties of Selected Transition-Metal Alloys (Alloys of Cr, Co, Hf, Mn, Mo, Ni, Nb, Pd, Pt, Rh, Ta, Ti, W, U, V, and Zr)
Volume IV-4. Properties of Selected Nontransition-Metal Alloys (Alloys of Al, Sb, Be, Bi, Cd, In, Pb, Mg, Sn, and Zn)
Volume IV-5. Properties of Copper Alloys, Gold Alloys, and Silver Alloys
Volume IV-6. Properties of Cermets

GROUP V. PROPERTIES OF FLUIDS AND FLUID MIXTURES

Volume V-1. Properties of Inorganic and Organic Fluids
Volume V-2. Properties of Commercial Refrigerants and Fluid Mixtures

GROUP VI. PROPERTIES OF OXIDES AND OXIDE MIXTURES

Volume VI-1. Properties of Rare-Earth Oxides and Actinide Oxides
(Oxides of Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ac, Th, Pa, U, Np, Pu, and Am)
Volume VI-2. Properties of Electronic Oxides
(Oxides of Cr, Co, Cu, Fe, Mn, Ni, Ti, V, and Zn)
Volume VI-3. Properties of Selected Nontransition-Metal Oxides
(Oxides of Al, Sb, Ba, Be, Bi, Cd, Ca, Cs, Fr, Ga, Ge, Au, In, Pb, Li, Mg, Hg, Po, K, Ra, Rb, Ag, Na, Sr, Tl, and Sn)
Volume VI-4. Properties of Selected Transition-Metal Oxides and Oxides of Selected Nonmetallic Solid Elements
(Oxides of Hf, Ir, Mo, Nb, Os, Pd, Pt, Re, Rh, Ru, Ta, Tc, W, Zr, As, B, P, Se, Si, and Te)
Volume VI-5. Properties of Complex Oxides
Volume VI-6. Properties of Oxide Mixtures
Volume VI-7. Properties of Ceramics and Glasses

GROUP VII. PROPERTIES OF COMMERCIAL GRAPHITES, COMPOSITES, AND SYSTEMS

Volume VII-1. Properties of Commercial Graphites and Carbon-Carbon Composites
Volume VII-2. Properties of Composites
(Other than Carbon-Carbon Composites)
Volume VII-3. Properties of Systems

GROUP VIII. PROPERTIES OF NON-OXIDE INORGANIC COMPOUNDS AND INTERMETALLIC COMPOUNDS

Volume VIII-1. Properties of Halides
(Bromides, Chlorides, Fluorides, and Iodides)
Volume VIII-2. Properties of Borides, Carbides, Hydrides, Nitrides, and Silicides
Volume VIII-3. Properties of Arsenides, Phosphides, Selenides, Sulfides, and Tellurides
Volume VIII-4. Properties of Carbonates, Nitrates, Phosphates, Silicates, and Sulfates
Volume VIII-5. Properties of Intermetallic Compounds

GROUP IX. PROPERTIES OF POLYMERS, ORGANIC COMPOUNDS, FOODS, BIOLOGICAL MATERIALS, AND BUILDING MATERIALS

Volume IX-1. Properties of Polymers
Volume IX-2. Properties of Organic Compounds, Foods, and Biological Materials
Volume IX-3. Properties of Building Materials

TABLE 13. PROPERTIES COVERED BY "McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"[a]

I. PROPERTIES PRESENTED AS A FUNCTION OF ONE OR MORE VARIABLES

A. Thermophysical Properties

1. Thermal Conductivity
2. Specific heat
3. Thermal linear expansion
4. Thermal diffusivity
5. Thermal emittance
6. Thermal reflectance
7. Thermal absorptance
8. Thermal transmittance
9. Solar absorptance to emittance ratio
10. Viscosity
11. Prandtl number[b]

B. Electrical, Electronic, Optical, and Magnetic Properties

12. Electrical resistivity
13. Thermoelectric power
14. Dielectric constant[c]
15. Hall coefficient
16. Optical constants (absorption index and refractive index)
17. Magnetic susceptibility

II. PROPERTIES PRESENTED AS A SINGLE VALUE OR FOR ROOM TEMPERATURE

A. Thermophysical Properties

18. Density (at NTP)
19. Normal melting point
20. Normal boiling point
21. Triple point
22. Critical temperature and pressure
23. Phase transition temperature
24. Magnetic transition temperature
25. Superconducting transition temperature
26. Debye temperature (at T)
27. Heat of fusion (at NMP)
28. Heat of vaporization (at NBP)
29. Vapor pressure (at T)

B. Electrical and Electronic Properties

30. Dielectric strength
31. Mobility
32. Energy gap
33. Work function

C. Mechanical Properties

34. Elastic constants (c_{ij})
35. Tensile strength
36. Yield strength
37. Compressive strength
38. Shear strength
39. Impact strength
40. Young's modulus
41. Compressive modulus
42. Shear modulus
43. Bulk modulus
44. Poisson's ratio
45. Hardness
46. Toughness
47. Creep rate
48. Velocity of sound (longitudinal and transverse)

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[a] Data on some of the properties are presented only for selected materials.

[b] Presented only for materials which are fluid at NTP.

[c] Presented only for long wavelengths ($\lambda > 100$ μm).

wavelength, etc. and further include twelve additional thermophysical properties, four additional electrical and electronic properties, and fifteen mechanical properties which are to be given for room temperature or as single values. It is important to note that the properties covered include not only all the important thermophysical, electronic, electrical, magnetic, and optical properties but also all the important room-temperature mechanical properties. Although mechanical properties are outside the scope of TEPIAC, it is believed that the inclusion of a large number of mechanical properties (even with values given for room temperature only) would increase the usefulness of the volumes significantly.

By the end of 1979, the following four volumes of the new CINDAS Data Series have been completed:

Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases
Volume II-2. Physical Properties of Rocks and Minerals
Volume III-1. Properties of Selected Ferrous Alloying Elements
Volume III-2. Properties of Nonmetallic Fluid Elements.

Volume II-1 has 475 pages (xxxvi + 439) and contains 1182 references (655 references to text on thermal accommodation coefficient, 206 references to data on thermal accommodation coefficient, and 321 references to gas adsorption). In addition to giving a most comprehensive review and discussion of the theories, methods of measurement, and methods of calculation and prediction of the thermal accommodation coefficient and of the gas adsorption, this volume presents 591 sets of experimental data on the thermal accommodation coefficient of 159 solid-gas systems and presents or describes 288 sets of experimental results on the gas adsorption of 36 solid-gas systems.

Volume II-2 has 570 pages (xxii + 548) and contains 77 tables, 266 figures, and 1797 references (1111 cited references and 686 references listed in appendices). It covers 29 thermal, electrical, magnetic, physical, and mechanical properties and 116 types of rocks and 222 minerals. In addition to properties of rocks and minerals, this volume contains information and data also on the constitution of rocks and on the heat flow from the crust of the United States.

Volume III-1 has 284 pages (xv + 269) and contains 91 tables, 107 figures, and 1736 references. It presents data and information on 43 properties of six selected ferrous alloying elements, which are: chromium, cobalt, iron, manganese, nickel, and vanadium. The 43 properties include 13 major properties which are presented as a function of one or more variables and 20 other properties which are given as a single value or for room temperature.

Volume III-2 has 224 pages (xv + 209) and contains 138 tables, 72 figures, and 269 references. It presents data and information on 15 properties of 19 nonmetallic fluid elements and isotopes, which are: argon, bromine, chlorine, deuterium, fluorine, helium-3, helium-4, normal hydrogen, ortho-hydrogen, para-hydrogen, iodine, krypton, neon, nitrogen, oxygen, ozone, radon, tritium, and xenon. The 15 properties include four major properties which are presented as a function of one or more variables and 11 others given as a single value or for room temperature.

The tables of contents of the four completed volumes of the new CINDAS Data Series reported above are given in Appendix 1 to show the scope of their coverage.

In 1979 another volume of data book entitled "Viscosity of Dense Fluids" was also completed. This volume is not in the CINDAS Data Series and was prepared in collaboration with two German scientists: Drs. K. Stephan and K. Lucas, who contributed technical work while TEPIAC provided bibliographic assistance, performed final editorial functions, and prepared the manuscript for publication. This volume has 280 pages (xii + 268), contains 376 references (166 references to text and 210 references to data sources), and presents 836 sets of recommended values (at 836 pressures) as a function of temperature for a total of 50 fluids. Additionally, this volume includes a review and discussion of the theories, methods of estimation, and techniques of correlation of the viscosity of dense gases and liquids. The table of contents of this volume is given in Appendix 2.

In addition to the work completed in 1979 as reported above, the work on Volume IV-1 entitled "Properties of Stainless Steels" has been in full progress, and in the meantime the works on the following six volumes have been initiated:

Volume I-1. Transport Properties of Fluids: Thermal Conductivity, Viscosity, and Diffusion Coefficient

Volume I-2. Transport Properties of Solids: Thermal Conductivity, Electrical Resistivity, and Thermoelectric Properties

Volume I-3. Specific Heat of Solids

Volume I-4. Thermal Expansion of Solids

Volume I-5. Thermal Radiative Properties of Solids

Volume VI-1. Properties of Rare-Earth Oxides and Actinide Oxides

4. STATE-OF-THE-ART REPORTS, CRITICAL REVIEWS, AND TECHNOLOGY ASSESSMENTS

In order to keep abreast of the user needs in relation to high-interest technology and information, TEPIAC has prepared and issued state-of-the-art reports, critical reviews, and technology assessments, which are special technical reports resulted, respectively, from comprehensive studies, extensive critical reviews, and short comparative assessments of current high-interest technology and information.

In this 12-month reporting period two major technical reports were completed, which are as follows.

(1) "Refractive Index of Silicon and Germanium and Its Wavelength and Temperature Derivatives," Purdue University, CINDAS Report 53, 132 pp., 1979.

This report contains the most comprehensively compiled experimental data and information on the refractive index of silicon and germanium and its wavelength and temperature derivatives, and presents also the recommended values resulted from the critical evaluation, analysis, and synthesis of the available data. Calculated values are given wherever experimental data are not available. The recommended values for the refractive index of silicon cover the range 1.2 to 14 μm and 100 to 750 K and those of germanium cover the range 1.9 to 16 μm and 100 to 550 K. Silicon and germanium are extremely important materials to the Defense community and have found numerous Defense applications in both infrared optics and electronics. They are also used in solar cells and thermoelectric devices to generate power for military satellites and other applications. Among the properties of silicon and germanium, the refractive index covered in this report plays a decisive role in the optical performance of the material, particularly in the design of infrared optical systems. Silicon and germanium are also brought into consideration for military high-power laser applications due to their high optical figure of merit, great mechanical strength, high chemical resistance, and availability in large size, even though their absorption coefficient at laser wavelengths is relatively high.

(2) "Thermophysical and Electrical Properties of Metal Matrix Composites," Purdue University, CINDAS Report 56, 264 pp., 1979.

This report presents the available experimental data and information on the thermophysical and electrical properties of 38 metal matrix composites, which are organized into eight groups according to the various metals constituting the matrices of the composites. Although the literature search was aimed at seeking data for all the thermophysical and electronic properties of all the metal matrix composites, data were found for only five properties. These are the thermal linear expansion, thermal conductivity, specific heat, thermal emittance, and electrical resistivity. The eight groups of metal matrix composites for which data were found are the various composites of aluminum and aluminum alloy matrices, copper matrix, lead matrix, magnesium matrix, nickel and nickel alloy matrices, titanium and titanium alloy matrices, tungsten matrix, and zinc matrix.

Three of the technical reports prepared previously for AMMRC and DLA have been published in this reporting period as formal publications in a well-known scientific journal. The three formal publications are:

(a) "Electrical Resistivity of Alkali Elements," Journal of Physical and Chemical Reference Data, 8(2), 339-438, 1979. [Originally CINDAS Report 40]

(b) "Electrical Resistivity of Alkaline Earth Elements," Journal of Physical and Chemical Reference Data, 8(2), 439-497, 1979. [Originally CINDAS Report 42]

(c) "Electrical Resistivity of Copper, Gold, Palladium, and Silver," Journal of Physical and Chemical Reference Data, 8(4), 1147-1298, 1979. [Originally CINDAS Report 46]

5. CARBON-CARBON COMPOSITES DATA BANK

The primary objective of this special project is to develop and establish a numerical data bank on the physical properties of carbon-carbon composites. This project is conducted in conjunction with MCIC/Battelle and the carbon-carbon composites are limited to a number of selected specific types. The responsibility of TEPIAC in this project is to cover the following five thermophysical properties:

(1) Thermal conductivity
(2) Specific heat
(3) Thermal expansion
(4) Thermal diffusivity
(5) Thermal radiative properties.

In addition to the data on specific types of carbon-carbon composite materials, data on carbon felt-type insulations are also of interest to this project.

At the beginning of this project, a thorough search through TEPIAC files for pertinent references was conducted and special retrospective searches were also conducted for TEPIAC by NTIS, DDC, and the Smithsonian Information Center at our request. A complete list of "Data Recording Parameters for Thermophysical Properties" was developed and subsequently was incorporated into the computer file structure for input of data into the data bank.

As data on the selected specific types of carbon-carbon composites and carbon felt-type insulations became available, they were extracted and carefully recorded according to the established format, and keyboarded for entry into the carbon-carbon composites data bank. So far 207 sets of data have been keyboarded and transmitted to Battelle for entry into the data bank.

In addition to the processing of data, descriptions of the experimental methods used by Southern Research Institute for measurements of the thermal linear expansion and the thermal conductivity for the PAN Pilot Production Program were prepared and revised. Study of the report by Fiber Materials, Inc. on Seven-Inch Man-Tech Billet Program was begun. One pertinent fact discovered was the mismatch in the thermal linear expansion data between the low-temperature and high-temperature data sets. Work was also initiated to reconstruct the P4 data using the established format developed by TEPIAC.

TEPIAC gave a status report on the thermophysical properties for the carbon-carbon composites data bank at the TI/TD meeting on November 28, 1979, held at Battelle Columbus Laboratories.

6. COMPUTERIZED NUMERICAL DATA STORAGE AND RETRIEVAL SYSTEM

Although TEPIAC has possessed a fully computerized bibliographic information storage and retrieval system capable of instant retrieval of all kinds of bibliographic information, the computerized numerical data storage and retrieval system is still under development. The development of this numerical data system was supported mainly through other sources.

This computerized numerical data storage and retrieval system will comprise two data files (data banks): one on evaluated numerical data (recommended values) and the other on unevaluated numerical data (raw experimental data).

For the evaluated numerical data bank, the overall design of the data bank and of the data capturing scheme had long been completed and the computer programming for storing the data has been finished. However, much remains to be done, especially in the computer programming phase of data retrieval and manipulation. Evaluated data extracted from seventeen data source references have been stored on magnetic tapes in this data bank, which currently contains 4,268 evaluated data sets (comprising 69,439 data points) on 15 properties of 1,764 materials. For the unevaluated numerical data bank no work has yet been done. This development work has been halted pending the continuation of funding.

This computerized numerical data system, when completed, should eventually be able to perform at least the following functions:

(1) Store and retrieve recommended reference data together with information on material identification and characterization and on data uncertainty.

(2) Store and retrieve experimental data together with information on specimen specification and characterization and on measurement method and condition.

(3) Manipulate data for data analysis, correlation, derivation, curve fitting, etc.

(4) Prepare tables, graphs, and list of references by computer for publication and for answering technical inquiries.

(5) Search for materials with given ranges of values of various properties.

(6) Be used for on-line computer search.

SECTION IV

INQUIRY SERVICES

TEPIAC's day-by-day contributions in inquiry services to individual users have been primarily in the nature of specialized advisory and technical consulting, data recommendation and prediction, and special bibliographic and data searches. During this 12-month reporting period 562 inquiries have been responded, of which 462 came from 44 states and the District of Columbia and 100 from 26 foreign countries. It is noted also that 69 of the 562 inquiries came from government laboratories and agencies, 136 from academic institutions, and 357 from defense contractors and other industrial organizations. Detailed statistical summary of inquiry responses for 1979 is presented in Table 14. Table 15 shows the geographical distribution of inquiry responses for 1979. A summary of inquiry responses for the last 17 years since 1963 is presented in Figure 17.

Over the years TEPIAC has developed a most efficient way for responding to technical and bibliographic inquiries. This is the result of our efficient "User Service Control System," which is based on the concept of having one staff member to be responsible for centralized control and coordination of requests and responses and using the contributions from various staff members whose expertises are in the areas of the requests. Furthermore, in order to expedite the service, TEPIAC accepts authorization for requests for normal technical and bibliographic inquiries by telephone as well as by letter or purchase order. All technical inquiry responses are recorded by the serial number, date, analyst (persons contributing to answering query), total hours, subject code, fee charged or service code, user codes, and mailing address. These recorded data are very useful for user service control and are also reported to the sponsor in the Quarterly R & D Contract Status Reports.

In order to assess the usefulness of TEPIAC's inquiry service and the degree of user satisfaction, a short questionnaire is sent to each inquirer together with the inquiry response (see Appendix 3 for a copy of TEPIAC Technical Inquiry Questionnaire). It should be noted that this simple questionnaire can be easily and quickly filled out by simple checks or short answers to questions. The information from the returned questionnaire is used as a feedback to our User Service Control System for constantly improving the quality of TEPIAC's inquiry service.

TABLE 14. STATISTICAL SUMMARY OF INQUIRY RESPONSES FOR 1979

	Information Request	Publication Request	Technical Question[a]	Bibliographic Search	TOTAL
DOMESTIC					
Government	18	2	24	7	51
Industry	99	33	125	56	313
University	29	16	37	16	98
Subtotal	146	51	186	79	462
FOREIGN					
Government	9	4	5	0	18
Industry	19	13	12	0	44
University	15	15	7	1	38
Subtotal	43	32	24	1	100
TOTAL	189	83	210	80	562

[a] Including data analysis and technical review.

Between 1 July 1977 and 31 December 1979, 1281 questionnaires were mailed out with our responses to inquirers. A total of 328 completed questionnaires were returned to TEPIAC. The rate of return was an outstanding 25.6 percent; most survey researchers would consider a 10 percent return to be excellent. The survey results from these returned questionnaires are presented in Appendix 4. It is very encouraging to note from the survey results that 18 percent of the users of TEPIAC technical inquiry services were "repeat customers". Note also that another 26 percent users were aware of TEPIAC through their co-workers, who must have given to them good recommendations about TEPIAC. Most users were pleased with TEPIAC responses to their inquiries, as 51% users rated the TEPIAC responses to be "very good," 38% users rated the responses to be adequate, while only 11% users considered the responses to be of marginal value. About 94% of the replies rated the TEPIAC inquiry service as prompt and 95% rated the charges reasonable, and only 4% considered the charges to be too high and 1% considered the charges too low. Perhaps the most important information obtained from these questionnaires was the value of the TEPIAC responses to the users. The survey results indicate that 39 percent of the responses saved the users 5 hours or less (these include the responses informing the users that no data/information

TABLE 15. GEOGRAPHICAL DISTRIBUTION OF INQUIRY RESPONSES FOR 1979

	No. of Inquiries
Alabama	9
Arizona	6
California	71
Colorado	10
Connecticut	10
Delaware	1
District of Columbia	15
Florida	5
Georgia	5
Hawaii	1
Idaho	3
Illinois	20
Indiana	25
Iowa	2
Kansas	1
Kentucky	2
Maine	1
Maryland	15
Massachusetts	24
Michigan	12
Minnesota	6
Mississippi	1
Missouri	5
Montana	2
Nevada	1
New Jersey	19
New Hampshire	1
New Mexico	10
New York	35
North Carolina	4
North Dakota	4
Ohio	36
Oklahoma	3
Oregon	4
Pennsylvania	26
Rhode Island	3
South Carolina	2
South Dakota	1
Tennessee	13
Texas	16
Utah	5
Virginia	12
Washington	8
West Virginia	1
Wisconsin	3
	462
Foreign Countries	100
TOTAL	562

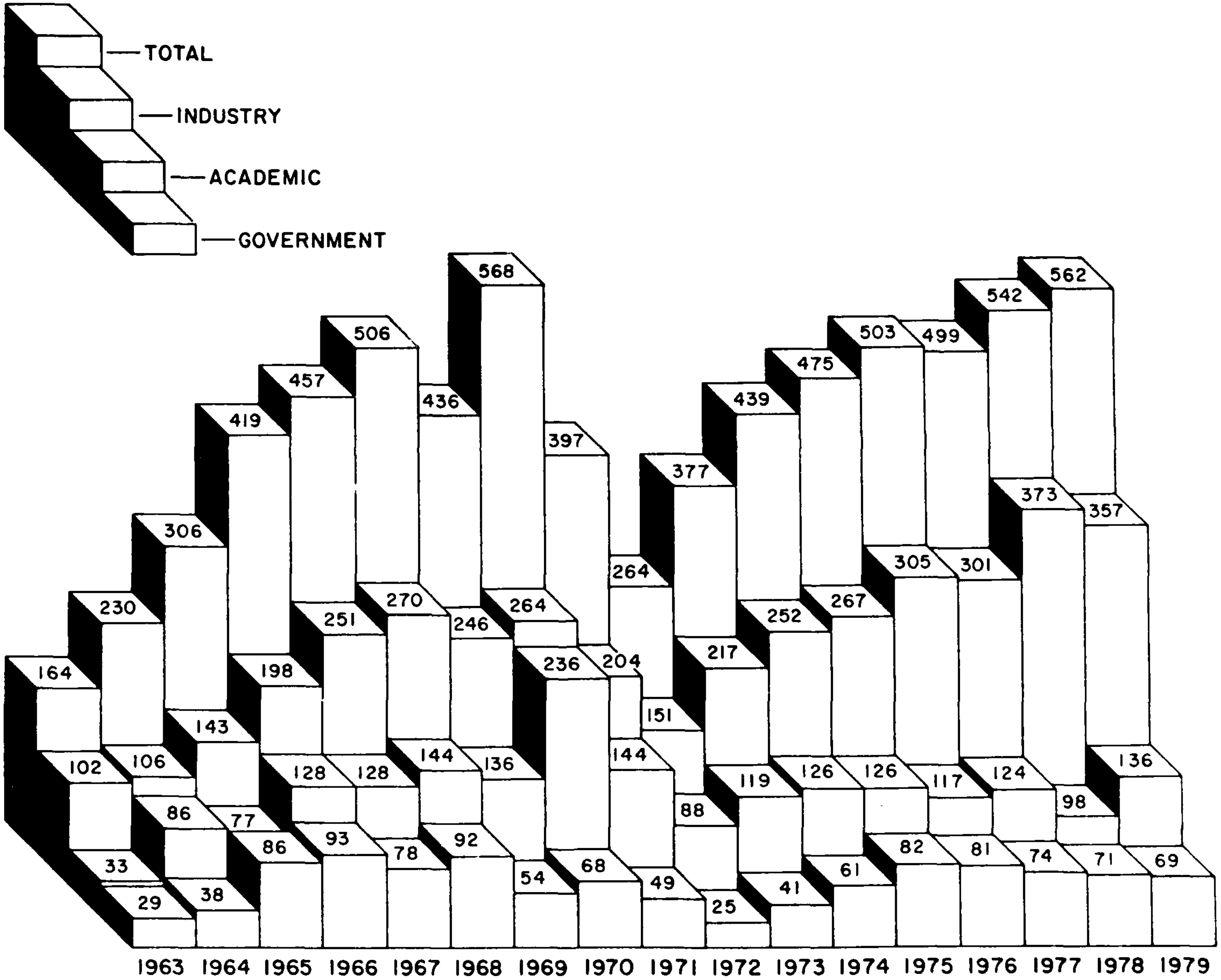

Figure 17. Summary of inquiry responses since 1963.

are uncovered from our exhaustive search for the properties of materials requested), 26 percent of the responses saved the users 40 hours or more, 14 percent of the responses saved the users 20 to 10 hours, another 14 percent saved the users 10 to 5 hours, and 7 percent of the responses saved the users 30 to 20 hours. Those larger savings (far exceeding 40 hours) were from inquiry responses that provided the users with numerical property data rather than bibliographic information. Typical comments of users on TEPIAC inquiry services are also listed in Appendix 4.

It is important to note that even though TEPIAC has provided excellent inquiry services to the users, these services impart only a relatively small portion of the total information and data that TEPIAC has provided to the users. The major portion of the information and data are provided to the users through TEPIAC's major publications. For example, two users commented "we are regularly using Volumes 1-13 of the Thermophysical Properties of Matter - The TPRC Data Series; these volumes are extremely useful in our research". Of course, there are numerous other unreported cases where users use the data and information contained in this and other major publications of TEPIAC. Consider this 13-volume 16,810-page TPRC Data Series alone, of which more than 1,000 sets have been sold. If it is assumed that each volume is used once a month by only one of the engineers or scientists in an organization who would save 40 hours (at $25 per hour) each time by obtaining and using the data and information from the TPRC Data Series, the total savings would be $156,000,000 per year. Even if each volume is used only once a year by only one person, the total savings would be $13,000,000 per year. If each volume is used by several persons, much larger savings to engineers and scientists would be achieved. Adding all the savings from all the major publications of TEPIAC over the years, one would realize how great a contribution TEPIAC has made.

TEPIAC has been maintaining a sound "Service Charge System" including an auditable detailed file of charges and users, and has been seeking its continual improvement. The nominal charges for TEPIAC products and services are as follows:

1. Bibliographic search. The nominal charge for a single bibliographic search is $35. A single bibliographic search is defined as a search for a maximum of five properties of one material for any temperature range and subject area. In the cases of special search requirements, price quotations are given.

2. Technical consultation, data recommendation, data synthesis and prediction. Minor technical assistance are provided at the rate of $25 per hour. Price quotations are given for extended technical services.

3. Publications. Brochures containing information on the content, availability, price, etc. are sent to requesters for information on major book and report publications. Copies of reprints of journal articles written by TEPIAC staff, if available, are sent to requesters free of charge.

4. Reproductions. The charge for microfiche reproduction is $2.50 per fiche. Hard copy reproduction is charged at $0.35 per page. A $3.00 special handling charge will be added to the total charge for an order under $10.00.

5. Promotional and current awareness products and general information on TEPIAC. These are provided at no cost.

Most routine users of scientific and technical information generally order and pay for TEPIAC's products and services through their local technical library or through their scientific and technical information office. TEPIAC has the following flexible payment options available:

1. Pre-paid account. This payment option allows an organization to deposit funds with TEPIAC/Purdue University. When TEPIAC delivers products or services in response to orders placed by organization's authorized employees, it will deduct the costs from the deposit account. The requester will be informed of the remaining dollar balance each time technical service is provided.

2. Telephone/letter authorization, pay later. A user may grant approval by telephone or letter for the performance of services for a specified nominal dollar value. TEPIAC provides the technical services to the requester, and Purdue University issues an invoice soon after, making reference to the purchase order number, if available, or to the authorization call or letter and the name of authorizing individual.

3. Standing order. This plan authorizes an organization to expend a specified amount of funds by anyone from the organization or by specified personnel only over a specified period. As products and

services are rendered, TEPIAC invoices the organization through Purdue University against this established standing order.

4. Blanket purchase agreement (BPA) or military deposit account. DOD agencies use this arrangement with a DD Form 1155 (order for supplies and services). A BPA according to the Armed Services Procurement Regulations (ASPR) is a "simplified method of filling anticipated repetitive needs for small quantities of supplies or services by establishing 'charge accounts' with qualified sources of supply. Blanket purchase agreements are designed to reduce administrative costs in accomplishing small purchases by eliminating the need for issuing individual purchase documents." In addition, BPA's allow for timely fulfillment of order.

It is interesting and informative to note those properties and materials on which information is most frequently requested by inquirers. Therefore, a study of the interest profile of all the technical inquiries in the 36-month period from 1 January 1977 to 31 December 1979 has been made and the findings are presented in Table 16. It can be observed from Table 16 that over 65% of the inquiries were on the top five of the 36 properties and top four of the material groups listed.

Since most users contacted TEPIAC for data and information via the telephone, TEPIAC has installed a national WATS line (No. 1-800-428-7675) to make it easier for all users to call TEPIAC toll free. TEPIAC has attempted a number of innovations in getting the word out and the WATS line is one of the contributions to establish a better and easier communication.

A list of organizations in the United States using TEPIAC inquiry services in the period 1 October 1975 to 31 December 1979 is given in Appendix 5.

TABLE 16. INTEREST PROFILE OF TECHNICAL INQUIRIES

(For the Period 1 January 1977 to 31 December 1979)

A. Properties (listed in the order of interest)

1.	Thermal Conductivity	23.5%
2.	Specific Heat	15.2%
3.	Thermal Linear Expansion	14.1%
4.	Electrical Resistivity	9.3%
5.	Thermal Diffusivity	6.8%
6.	Viscosity	5.8%
7.	Emittance	4.2%
8.	Refractive Index	4.2%
9.	Reflectance	3.3%
10.	Absorptance	3.0%
11.	Transmittance	2.1%
12.	Dielectric Constant	1.9%
13.	Dielectric Strength	0.8%
14.	Magnetic Susceptibility	0.7%
15.	Absorption Coefficient	0.7%
16.	Thermoelectric Properties	0.7%
17.	Magnetic Hysteresis	0.3%
18.	Mobility	0.3%
19.	Thermal Volumetric Expansion	0.3%
20.	Energy Levels	0.3%
21.	Thermal Cantact Resistance	0.3%
22.	Energy Bands	0.2%
23.	Energy Gap	0.2%
24.	Work Function	0.1%
25.	Misc. (9 Electrical + 3 Thermo.)	1.7%

B. Materials (listed in the order of interest)

1.	Inorganic Compounds	26.1%
2.	Elements	18.4%
3.	Non Ferrous Alloys	11.7%
4.	Ferrous Alloys	9.4%
5.	Intermetallics	6.0%
6.	Composites and Systems	5.2%
7.	Polymers	5.2%
8.	Glasses, Refractories, etc.	4.6%
9.	Minerals	4.6%
10.	Organic Compounds[a]	3.4%
11.	Hydrocarbons	1.3%
12.	Solutions and Mixtures	0.9%
13.	Foods	0.8%
14.	Cermets	0.5%
15.	Coatings	0.4%
16.	Miscellaneous	1.5%

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[a] Excluding hydrocarbons.

SECTION V

CURRENT AWARENESS AND PROMOTION EFFORTS

The "Thermophysics and Electronics Newsletter" has been issued bimonthly since January 1972 to a circulation list of TEPIAC users and potential users as a means of keeping them abreast of significant developments and coming events, the availability of new information and publications, the initiation of new R & D programs, and of the availability of products and services from TEPIAC. The number of names in the mailing list has been increasing slowly and reached 11,000. In this 12-month period 6 issues of the Newsletter have been released with a total of 66,000 copies distributed.

The development of an enlarged and computerized mailing list for TEPIAC users and potential users has been accomplished. A simple profile code is given to each name on the mailing list so that the computer can generate selective mailing lists from a master file. The new mailing list therefore not only covers a greater percentage of TEPIAC's total audience, but also allows the isolation of selected portions of that audience for specialized mailings, which increases the effectiveness of the mailing and saves much money in dissemination costs.

In order to ensure that TEPIAC users and potential users are aware of the Center, the products and services it offers, and the benefits to be realized through use of the Center, promotional brochures and users guide are periodically issued and distributed, in addition to the distribution of the bimonthly Newsletter. Three new promotional brochures, two with 4 pages and the other with 2 pages, have been produced in this reporting period to make the users and potential users better acquainted with TEPIAC' functions, capabilities, technical assistance, products, and services.

In this 12-month period TEPIAC sponsored the Sixteenth International Thermal Conductivity Conference and the Seventh International Thermal Expansion Symposium, which were held at Chicago on November 7-9, 1979. Furthermore, TEPIAC staff participated in 14 other conferences and meetings. A list of these 16 conferences and meetings is given in Table 17.

TEPIAC has maintained periodic contacts with a number of national and international experts in the field of thermophysics and thermophysical and

TABLE 17. CONFERENCES AND MEETINGS PARTICIPATED IN BY TEPIAC STAFF MEMBERS IN THE PERIOD 1 JANUARY TO 31 DECEMBER 1979

Name	Location	Date
Seminar on "Minicomputer Data Base Management System"	Elmhurst, IL	Feb. 22, 1979
Carbon-Carbon Composites Data Bank Meeting	Dayton, OH	Feb. 23, 1979
ASTM Thermal Measurements Committee Meeting	Cincinnati, OH	March 22-23, 1979
Award Ceremony for an Award by Gould, Inc., with an Award Acceptance Speech on the History, Operation, Capabilities, Products, and Services of TEPIAC/CINDAS	Rolling Meadows, IL	April 20, 1979
Meeting on Carbon-Carbon Composites Data Bank	Dayton, OH	May 9-10, 1979
Symposium on Atomic Spectroscopy-1979	Tucson, AZ	Sept. 10-14, 1979
Meeting of ICSU-CODATA Task Group on Thermophysical Properties of Solids	Mol, Belgium	Sept. 24-25, 1979
Plenary Meeting for the Preparation of the 7th European Thermophysical Properties Conference	Mol, Belgium	Sept. 26, 1979
Eleventh Annual Symposium on Optical Materials for High Power Lasers	Boulder, CO	Oct. 30-31, 1979
High Power Laser Optical Components Conference	Boulder, CO	Nov. 1-2, 1979
Sixteenth International Thermal Conductivity Conference	Chicago, IL	Nov. 7-9, 1979
Seventh International Thermal Expansion Symposium	Chicago, IL	Nov. 7-9, 1979
Meeting of ASTM Committee on Thermal Diffusivity	Chicago, IL	Nov. 7, 1979
Carbon-Carbon Composites Data Bank TI/TD Meeting	Columbus, OH	Nov. 27-28, 1979
Carbon-Carbon Composites Data Bank Technical Meeting	Dayton, OH	Dec. 13, 1979
DOD Information Analysis Centers Directors/Managers Meeting	Alexandria, VA	Dec. 17, 1979

electronic properties and has developed cooperative working arrangements with a number of national and international laboratories and institutions engaged in thermophysical and/or electronic properties research for the exchange of ideas, technical information, and research results.

As part of the continuing effort to bring about improved awareness of the need and value of using evaluated reference data versus data directly taken from the literature and of the benefits to be realized through the use of Information Analysis Centers such as TEPIAC, a documentary film entitled "The Anatomy of Data" was produced. "The Anatomy of Data" points out and stresses the serious discord that exists among the data of science and technology as reported in the scientific and technical literature. Through on-location interviews with prominent scientists highly knowledgeable in this field, and using examples drawn from our files, the film illustrates the serious pitfalls an engineer or scientist may fall into unless he uses critically evaluated data prepared by such National Information Analysis Centers as TEPIAC. The role and usefulness of data synthesis is also stressed and demonstrated. This movie has been shown to about 184 organizations in this country and abroad.

On 20 April 1979 TEPIAC/CINDAS received an Award from Gould, Inc. at Gould Center, Rolling Meadows, Illinois for excellence in TEPIAC/CINDAS' performance. It is indeed rewarding to know that our efforts are so recognized as effective and worthwhile for such award from a leading corporation.

SECTION VI

OTHER PUBLICATIONS NOT UNDER THIS CONTRACT BUT IN DIRECT SUPPORT OF THIS PROGRAM

In the following are listed some selected technical products produced in this same period which are not under this contract but are in direct support of this program. Thus, CINDAS' other activities have benefited this program greatly.

1. "Absorption Coefficient of Alkali Halides (Part I)," Purdue University, CINDAS Report 54, 278 pp., 1979.
2. "Absorption Coefficient of Alkali Halides (Part II)," Purdue University, CINDAS Report 55, 148 pp., 1979.
3. "Data Analysis for Defense," National Defense, 63(354), 45-9, 1979.
4. "The Need of Science for Evaluated Information," Bulletin of the American Society for Information Science, 5(6), 44, 1979.
5. *Masters Theses in the Pure and Applied Sciences Accepted by Colleges and Universities of the United States and Canada*, Vol. 23, Plenum Press, New York, N.Y., 292 pp., 1979. This has been an annual publication of CINDAS with its first volume published in 1957. A brief statistical summary of coverage of this publication is given in Table 18. Table 19 shows a complete list of academic disciplines covered by the publication.

TABLE 18. STATISTICAL SUMMARY OF COVERAGE OF "MASTERS THESES IN THE PURE AND APPLIED SCIENCES"

Volume No.	Publication Date	Thesis Year	No. of Pages	No. of Contributing Institutions	No. of Thesis Titles Reported
1	Oct. 1957	1955	108	93	1,002
		1956		93	1,027
2	Aug. 1958	1957	104	154	1,727
3[a]	Oct. 1959	1958	500	139	3,736
4	Dec. 1960	1959	443	162	4.984
5	Dec. 1961	1960	443	183	5,708
6	Aug. 1966	1961	127	186	5,911
7	Aug. 1966	1962	133	186	6,321
8	Aug. 1966	1963	143	175	6,505
9	Jan. 1968	1964	146	174	6,940
10	Jan. 1968	1965	156	170	7,310
11	Jan. 1968	1966	150	173	7,099
12	July 1968	1967	148	167	6,909
13	July 1969	1968	166	174	7,802
14	Jan. 1971	1969	151	175	7,160
15	July 1971	1970	153	183	7,413
16	July 1972	1971	152	182	7,170
17	July 1973	1972	179	250	8,513
18[b]	Dec. 1974	1973	286	251	10,381
19	Dec. 1975	1974	285	229	10,045
20	Dec. 1976	1975	293	267	10,374
21	Nov. 1977	1976	290	244	10,586
22	Oct. 1978	1977	305	255	10,658
23	Nov. 1979	1978	292	247	10,432

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[a] Volume 3 includes also doctoral dissertations for 1956-57 academic year, citing 2846 titles from 103 universities.

[b] Effective with Volume 18, the coverage has been extended to include Canadian universities.

TABLE 19. ACADEMIC DISCIPLINES COVERED BY THE "MASTERS THESES IN THE PURE AND APPLIED SCIENCES"[a]

1. Aerospace Engineering
2. Agricultural Economics, Sciences and Engineering
3. Architectural Engineering and Urban Planning
4. Astronomy
5. Astrophysics
6. Ceramic Engineering
7. Chemical Engineering
8. Chemistry and Biochemistry
9. Civil Engineering
10. Communications Engineering and Computer Science
11. Cryogenic Engineering
12. Electrical Engineering
13. Engineering Mechanics
14. Engineering Physics
15. Engineering Science
16. Fuels, Combustion and Air Pollution
17. General and Environmental Engineering
18. Geochemistry and Soil Science
19. Geological Sciences and Geophysical Engineering
20. Geology
21. Geophysics
22. Industrial Engineering and Operations Research
23. Irrigation Engineering
24. Marine and Ocean Engineering
25. Materials Science and Engineering
26. Mechanical Engineering and Bioengineering
27. Metallurgy
28. Meteorology and Atmospheric Sciences
29. Mineralogy and Petrology
30. Mining and Metallurgical Engineering
31. Missile and Space Systems Engineering
32. Nuclear Engineering
33. Nuclear Physics
34. Nuclear Science
35. Oceanography and Marine Science
36. Petroleum and Natural Gas Engineering
37. Photogrammetric and Geodetic Engineering
38. Physics and Biophysics
39. Plastics Engineering
40. Wood Technology, Forestry and Forest Science
41. Reactor Science
42. Sanitary Engineering and Water Pollution and Resources
43. Textile Technology
44. Transportation Engineering

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[a] Mathematical and most life sciences have been excluded on a purely arbitrary basis simply to limit the scope of the work.

SECTION VII

CONCLUSIONS AND FUTURE PLANNING

This Annual Final Report has covered all the tasks and activities of the Thermophysical and Electronic Properties Information Analysis Center in the 12-month reporting period 1 January to 31 December 1979 and has contained details of all technical work accomplished and information gained in the performance of the contract.

TEPIAC has been maintaining a comprehensive, authoritative, and up-to-date national data base on thermophysical, electronic, electrical, magnetic, and optical properties of all important materials, and has been disseminating the resulting data and information to the entire DOD community and general TEPIAC users at large through the publication of major reference works on property data and information and of other technical products and at the same time has been providing the much needed data and information directly to individual users through technical and bibliographic inquiry and authoritative information and data analysis services. As the objective of TEPIAC operations is to increase the productivity of scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense by maintaining a comprehensive and up-to-date national data base for use by the entire DOD community and by providing authoritative information and data analysis services, it is obvious that the objective of TEPIAC operations has been achieved most successfully. In fact, the accomplishments of TEPIAC have far exceeded the requirements of the contract. Under CINDAS' operation, TEPIAC has long achieved the full operational status of a Full-Service DOD Information Analysis Center. TEPIAC has been well oriented to the needs of its user community, and its products and services are well-known nationally and, indeed, internationally.

As CINDAS operates through the multiple sponsorship of organizations having a common interest in property data and information, the results obtained from the support provided by one group benefits all others. Therefore, the supports from all other sources have benefited this contract greatly. Since the supports from other sources have been approximately equal to that from DLA, TEPIAC/CINDAS has been returning to DLA the results of two dollars of research for every dollar invested by the DLA. Thus TEPIAC has met its additional goal of achieving an annual rate of income from its products, services, and other financial supports equal to at least 50% of the initial DLA annual funding of this contract.

Due to the disturbing fact that the existing data and information on material properties recorded in the scientific and technical literature are often conflicting, widely diverging, and subject to large uncertainty, TEPIAC has traditionally stressed data evaluation, analysis, and synthesis, and the generation of evaluated reference data, even though TEPIAC is a full-service Information Analysis Center. As a result, TEPIAC can provide to its users not only just any or all available data and information, but also the evaluated correct data and information, and furthermore in many cases TEPIAC can also provide predicted data and information to the users even when the needed data and information are completely lacking and nonexisting.

In future years TEPIAC will continue to be operated as a full-service DOD Information Analysis Center using the methods and procedures developed and fully established at CINDAS over the years for the most efficient and effective service to the Department of Defense and its scientific and technical community. The past successful performance of TEPIAC assures continued future success in achieving its objective and goal and accomplishing all its tasks.

Among the tasks of TEPIAC, the preparation and publication of volumes in the new CINDAS Data Series on Material Properties is one that should gain much greater momentum, as TEPIAC/CINDAS has always felt that the maximum optimization of its efforts in serving the end-user of data and information can best be realized through the publication of major reference works. Due to the low funding level of this program, the level of effort that can be devoted to this most important task is believed far too low. It is earnestly hoped that the level of effort for the data book preparation can be increased so that more volumes of the new CINDAS Data Series can be produced in a timely manner.

In addition to our Data Series, it is appropriate at this time to also review briefly some of the new major products we anticipate to complete during 1980; these are:

1. Publication of a new six-volume "Retrieval Guide to Thermophysical Properties Research Literature" which would merge together the present Basic Edition, Supplement I, and Supplement II. This would create a most convenient reference work for users.

2. Preparation of bibliographic computer tapes, for lease or license, representing TEPIAC's new retrieval system to be referred to as the Thermophysical and Electronic Properties Information System (TEPIS).
3. Development of an interactive numerical data base of evaluated numerical data on thermophysical and electronic properties.

These above major products were in the development stage for sometime under multiple support, however, the low level of funding has required a longer period of time than originally anticipated.

APPENDICES

APPENDIX 1. TABLE OF CONTENTS OF THE FOUR COMPLETED VOLUMES OF THE "McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"

VOLUME II-1. THERMAL ACCOMMODATION AND ADSORPTION COEFFICIENTS OF GASES

VOLUME II-2. PHYSICAL PROPERTIES OF ROCKS AND MINERALS

TABLE OF CONTENTS

CHAPTER 1 - CONSTITUTION OF ROCKS

CHAPTER 2 - PARAMETRIC CONSIDERATIONS

CHAPTER 3 - DENSITY

CHAPTER 4 - POROSITY, PERMEABILITY, DISTRIBUTION COEFFICIENTS, AND DISPERSIVITY

CHAPTER 5 - STRENGTH OF ROCK

CHAPTER 6 - STATIC STRESS-STRAIN RELATIONSHIP

CHAPTER 7 - SHEAR RESISTANCE AND DEFORMABILITY OF ROCK DISCONTINUITIES

CHAPTER 11 - MELTING CURVES OF ROCKS AND VISCOSITY OF ROCK-FORMING MELTS

CHAPTER 12 - THERMOPHYSICAL PROPERTIES OF ROCKS

CHAPTER 13 - HEAT FLOW FROM THE CRUST OF THE UNITED STATES

VOLUME III-1. PROPERTIES OF SELECTED FERROUS ALLOYING ELEMENTS

CONTENTS

AD-A083 943 CENTER FOR INFORMATION AND NUMERICAL DATA ANALYSIS AN--ETC F/G 5/2
THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS C--ETC(U)
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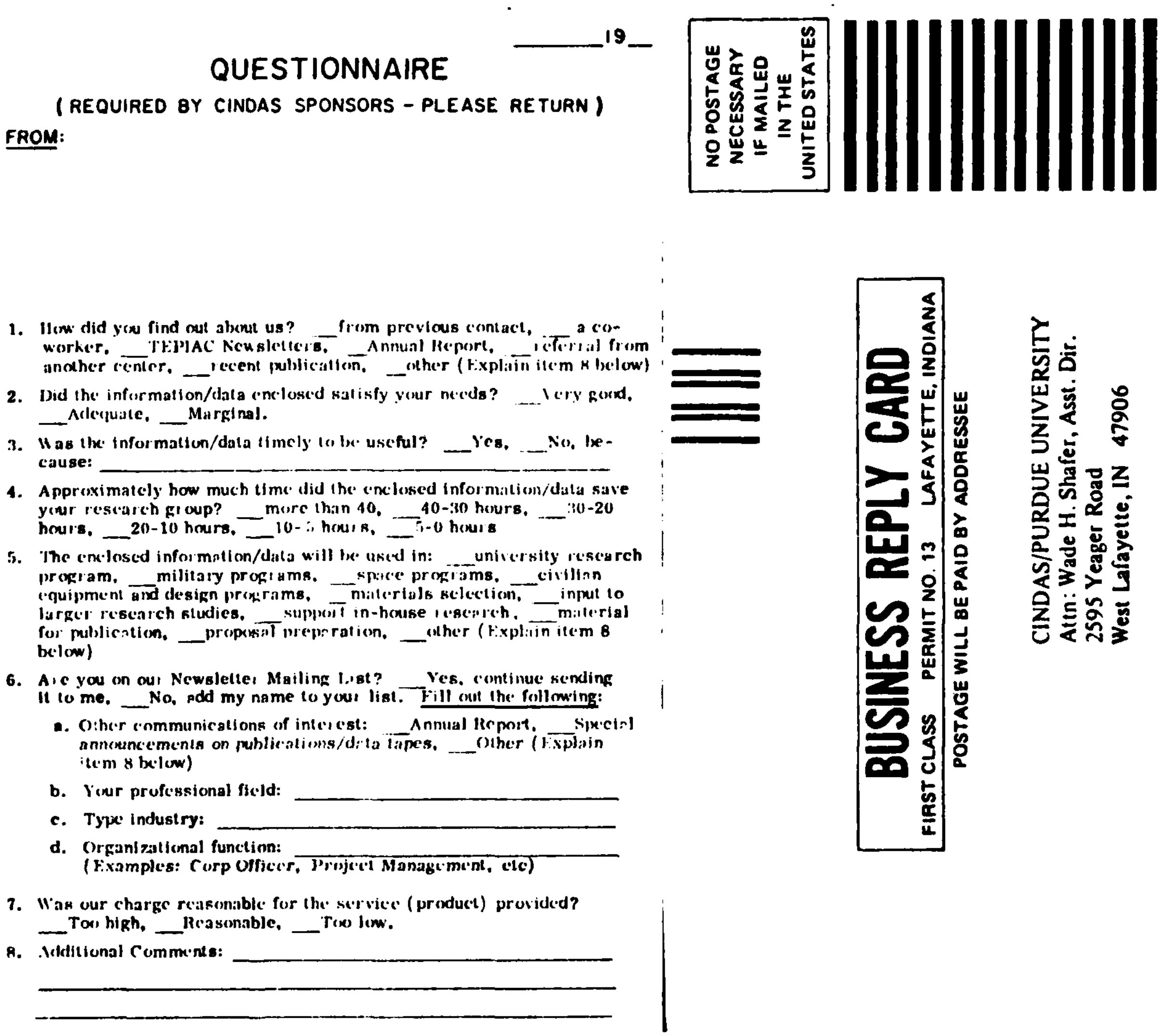
VOLUME III-2. PROPERTIES OF NONMETALLIC FLUID ELEMENTS

TABLE OF CONTENTS

APPENDIX 2. TABLE OF CONTENTS OF THE COMPLETED DATA BOOK ENTITLED "VISCOSITY OF DENSE FLUIDS"

APPENDIX 3

TEPIAC TECHNICAL INQUIRY QUESTIONNAIRE



_______19__

QUESTIONNAIRE

(REQUIRED BY CINDAS SPONSORS - PLEASE RETURN)

FROM:

1. How did you find out about us? __from previous contact, ___a co-worker, ___TEPIAC Newsletters, __Annual Report, __referral from another center, ___recent publication, __other (Explain item 8 below)
2. Did the information/data enclosed satisfy your needs? __Very good, ___Adequate, ___Marginal.
3. Was the information/data timely to be useful? ___Yes, __No, because: ______________________________
4. Approximately how much time did the enclosed information/data save your research group? ___more than 40, ___40-30 hours, ___30-20 hours, ___20-10 hours, ___10-5 hours, ___5-0 hours
5. The enclosed information/data will be used in: ___university research program, ___military programs, ___space programs, ___civilian equipment and design programs, __materials selection, ___input to larger research studies, ___support in-house research, ___material for publication, ___proposal preparation, ___other (Explain item 8 below)
6. Are you on our Newsletter Mailing List? ___Yes, continue sending it to me, ___No, add my name to your list. Fill out the following:
   - a. Other communications of interest: ___Annual Report, ___Special *announcements on publications/data tapes*, ___Other (Explain item 8 below)
   - b. Your professional field: ______________________________
   - c. Type industry: ______________________________
   - d. Organizational function: ______________________________
     (Examples: Corp Officer, Project Management, etc)
7. Was our charge reasonable for the service (product) provided? ___Too high, ___Reasonable, ___Too low.
8. Additional Comments: ______________________________

____

____

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UNITED STATES

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO. 13 LAFAYETTE, INDIANA

POSTAGE WILL BE PAID BY ADDRESSEE

CINDAS/PURDUE UNIVERSITY
Attn: Wade H. Shafer, Asst. Dir.
2595 Yeager Road
West Lafayette, IN 47906

APPENDIX 4

SURVEY RESULTS FROM TEPIAC TECHNICAL INQUIRY QUESTIONNAIRE

Between 1 July 1977 and 31 December 1979 (30 months), 1281 TEPIAC Technical Inquiry Questionnaires were mailed out with inquiry responses to inquirers. A total of 328 questionnaires were returned; this is a 25.6 percent return. There are eight questions listed in the questionnaire (see Appendix 3). The responses to each of the eight questions are detailed below.

1. How did you find out about us?

From a co-worker	84	(25.6%)
From a previous contact	60	(18.3%)
From TEPIAC Newsletters	52	(15.9%)
From TEPIAC recent publications	37	(11.3%)
Referral from another center	35	(10.7%)
From CINDAS Annual Reports	11	(3.3%)
From other sources	49	(14.9%)
Total	328	

Typical "other sources" given in the responses are:

"Our information group"
"Reference librarian"
"Frequent use of your publications"
"Brochures mailed to me"
"CINDAS brochures"
"NTIS brochure"
"Critical survey of data sources, NBS (Dec. 75)"
"June issue of R/D magazine"
"CRC handbook"
"A US lecturer on medical physics"
"ASHRAE fundamentals book"
"Kruzas Encyclopedia of Information Systems and Services"
"At ASM Chicago Meeting 1977"
"Via North American Thermal Analysts Society (NATAS)"
"User Guide - DOD Information Analysis Center"
"National Bureau of Standards"
"Recommended by a Major Supplier"
"Article in May-June 1979 issue of National Defense"
"Lecture Series at Battelle"

2. Did the information/data enclosed satisfy your needs?

Very good	156	(51.2%)
Adequate	117	(38.3%)
Marginal	32	(10.5%)
Total	305[a]	

3. Was the information/data timely to be useful?

Yes	258	(93.8%)
No (because no data are available)	17	(6.2%)
Total	275[a]	

4. Approximately how much time did the enclosed information/data save your research group?

5-0 hours	66	(38.7%)
More than 40 hours	45	(26.3%)
20-10 hours	24	(14.0%)
10-5 hours	24	(14.0%)
30-20 hours	12	(7.0%)
Total	171[a]	

5. The enclosed information/data will be used in:

Support in-house research	83	(25.3%)
Civilian equipment and design programs	49	(14.9%)
Input to larger research studies	42	(12.8%)
Materials selection	38	(11.6%)
Military programs	35	(10.7%)
Space programs	26	(7.9%)
University research program	25	(7.6%)
Material for publication	16	(4.9%)
Proposal preparation	14	(4.3%)
Total	328	

6. Are you on our Newsletter Mailing List?

No, add my name to your list	200	(68.3%)
Yes, continue sending it to me	93	(31.7%)
Total	293[a]	

7. Was our charge reasonable for the service (product) provided?

Reasonable	183	(94.9%)
Too high	8[b]	(4.1%)
Too low	2	(1.0%)
Total	193[a]	

8. Additional Comments:

Typical "additional comments" given in the responses are:

"I was surprised that the information was found at all - let alone quickly"

"I received a very quick answer to my request for data on thermal expansion of steel"

"Very comprehensive work in your area"

"A tremendous amount of savings in time can be realized with the proper use of this valuable resource"

"Our own group unable to locate any references"

"We could not have done the job"

"We had exhausted all other possible sources"

"Estimate reduction of search time by 90 percent"

"We are regularly using Volumes 1-13 of the Thermophysical Properties of Matter - The TPRC Data Series; these volumes are extremely useful in our research"

"Very pleased with speed and accuracy of your reply"
"I appreciate the friendly and helpful manner you have when dealing with clients"
"Thank you for the assistance that you gave during our telephone conversation"
"You are fulfilling a very worthwhile service and we will continue to turn our service requirements your way"
"Brochures appear to have useful infromation to be utilized in materials selection for off shore petroleum production platforms"
"In the future I expect your service will be very helpful"
"We hope to use TEPIAC in the future"
"Our tendency is to turn to CINDAS only when all other information sources are inadequate, but it is reassuring to industries such as ours to have this back-up"
"The response from Mr. Shafer was rapid and to the point. I appreciate this type of response"
"You people write nice letters"
"This critical evaluation of research data is extremely valuable to the scientific and engineering communities"
"Appreciated the cordiality and helpfulness of Mr. Shafer"
"Your center has repeatedly been referenced as a prime source of information in my area of research"
"I foresee a need for this type of service in the future - next time I will start with TEPIAC search"
"You offer a valuable service which is much appreciated"
"Very honest and reasonable data source"
"Estimate man-hour savings at 400 hours per year"
"Saved our lab testing time more than 40 hours"
"Very pleased with searches"
"Your objectives are very important and of great help to science and engineering fields"
"Very quick response"
"The service is fast and reliable, it should be better known"
"Service is excellent"
"Your people were very helpful and I will use your organization when needed"
"Prompt service was much appreciated"

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[a] "No responses" are not included in the statistics - a total of 328 questionnaires were returned.

[b] Six of the eight responses saying the charge being too high were from university students/faculty members and small company employees.

APPENDIX 5

ORGANIZATIONS USING TEPIAC INQUIRY SERVICES[a]

(In the Period 1 October 1975 to 31 December 1979)

AAI Corp.
Baltimore, MD

A. B. Chance Co.
Centralia, MO

ACRES American
Buffalo, NY

Action Research
Acton, MA

Actron, Inc.
Monrovia, CA

Acurex Corp.
Mountain View, CA

Aero Mechanical Engr. Lab.
Tucson, AZ

Aerojet Electrosystems
Azusa, CA

Aerojet Nuclear Co.
Idaho Falls, ID

Aerospace Corp.
Los Angeles, CA

Aerospace Research Applications Center
Indianapolis, IN

Air Force Avionics Lab.
Wright-Patterson Air Force Base, OH

Air Force Materials Laboratory
Wright-Patterson Air Force Base, OH

Air Force Office of Scientific Research
Bolling Air Force Base, DC

Air Force Rocket Propulsion Laboratory
Edwards Air Force Base, CA

Air Force Weapons Laboratory
Kirkland Air Force Base, NM

Air Products and Chemical Co.
Allentown, PA

AIRCO, Inc.
Murray Hill, NJ

Air Research Manufacturing
Phoenix, AZ

Alabama A & M University
Huntsville, AL

Alabama A & M University
Normal, AL

Allegheny Ballistics Laboratory
Cumberland, MD

Allegheny Ludlum Steel Corp.
Pittsburgh, PA

Allied Chemical Co.
Idaho Falls, ID

Allied Chemical Corp.
Morristown, NJ

Aluminum Company of America
Alcoa Center, PA

American Home Foods, Inc.
LaPorte, IN

American Iron and Steel Institute
Washington, DC

American Thermocraft Corp.
East Orange, NJ

AMF Incorporated
Stanford, CT

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[a] Only organizations within the United States are listed.

Amoco Chemical Co.
Naperville, IL

AMP Incorporated
Harrisburg, PA

Anaconda Brass Co.
Waterbury, CT

Anaconda Co.
Marion, IN

Anamet Lab., Inc.
San Carlos, CA

Argonne National Laboratories
Argonne, IL

Arizona State University
Tempe, AZ

Army Materials & Mechanics Research Center
Watertown, MA

Arthur D. Little, Inc.
Cambridge, MA

Ashland Chemical Co.
Columbus, OH

Asin Seiki Co., Ltd.
Troy, MI

Atlantic Research Center
Alexandria, VA

Atlantic Richfield Hartford Co.
Richland, WA

Atomic Energy Documentation Service
Larchmont, NY

Atomic International
Canoga Park, CA

Autonetics, Inc.
Anaheim, CA

Babcock & Wilcox, Research & Development
Alliance, OH

Babcock & Wilcox Co.
Lynchburg, VA

Baker & Taylor Co.
Momence, IL

Baker & Taylor Co.
Somerville, NJ

Ball Corp.
Muncie, IN

Barber Colman Co.
Loves Park, IL

Bartlesville Energy Research Center
Bartesville, OK

Battelle Columbus Laboratories
Columbus, OH

Battelle-Northwest
Richland, WA

BDM Corp.
Dayton, OH

Bechtel Corp.
San Francisco, CA

Bechtel Power Co.
San Francisco, CA

Bechtel Tower Corp.
Gaithersburg, MD

Bell Aerospace/Textron
Buffalo, NY

Bell Laboratories
Allentown, PA

Bell Telephone Laboratories, Inc.
Murray Hill, NJ

Bendix Corp.
Dayton, OH

Bendix Corp.
Davenport, IA

Bendix Corp.
Kansas City, MO

Bendix Research Laboratory
South Field, MI

Bettis Atomic Power Laboratories
W. Mifflin, PA

Black and Veatch, Inc.
Kansas City, MO

Boeing Aerospace Co.
Houston, TX

Boeing Co.
Seattle, WA

Boeing Computer Services
Richland, WA

Borg Warner Corp.
Des Plaines, IL

Breed Corp.
Fairfield, NJ

Bresler and Associates
New York, NY

Bricmont & Associates, Inc.
McMurray, PA

Brigham Young University
Provo, UT

Brockway Glass Co.
Brockway, PA

Brookhaven National Laboratories
Upton, NY

BRL/Aberdeen Proving Ground
Aberdeen, MD

Brunswick Corp.
Skokie, IL

Bunker Ramo Corp.
Chatsworth, CA

Burns and Roe Co.
Hempstead, NY

Burroughs Corp.
San Diego, CA

CABOT Corp.
Billerica, MA

California Institute of Technology
Pasadena, CA

California State University
Fullerton, CA

Calspan Corp.
Buffalo, NY

Carborundum Co.
Niagara Falls, NY

Carnegie Mellon University
Pittsburgh, PA

Carrier Corp./Research Division
Syracuse, NY

Carson Alexion Corp.
Costa Mesa, CA

Case Western Reserve University
Cleveland, OH

Caterpillar Tractor Co.
Peoria, IL

Catholic University
Washington, DC

CHEMETAL Corp.
Pacoima, CA

Chem. Shore Corp.
Houston, TX

Chicago Urban Transportation District
Chicago, IL

Chi-Vit Co.
Oakbrook, IL

Chrysler Corp.
Detroit, MI

Cincinnati Electronics Corp.
Cincinnati, OH

Cincinnati Inc.
Cincinnati, OH

Climax Molybdenum Co.
Ann Arbor, MI

Colorado State University
Fort Collins, CO

Columbia Gas Systems
Columbus, OH

Columbia University
New York, NY

Combustion Engineering
Chattanooga, TN

COMSAT Laboratories
Clarksburg, MD

Consolidated Aluminum Service Center
St. Louis, MO

Cordis Corp.
Miami, FL

Cornell University
Ithaca, NY

Cornell University
Utica, NY

Corning Glass Works
Corning, NY

Coulter Systems Corp.
Bedford, MA

CS Draper & Laboratory
Cambridge, MA

CTI Cryogenics
Waltham, MA

Curtiss-Wright Corp.
Woodridge, NJ

Daniel Construction Co.
Greenville, SC

DCM Associates
San Francisco, CA

Deere and Co.
Moline, IL

Defense Logistics Agency
Alexandria, VA

Department of Transportation
Washington, DC

Department of Interior Library
Washington, DC

Dert Industries
Paramus, NY

Desota, Inc.
Des Plaines, IL

Detrick Co.
Chicago, IL

Deutch Co.
Los Angeles, CA

DIGICOLOR
Columbus, OH

Dixie College
St. George, UT

Dow Chemical Co.
Freeport, TX

Dow Chemical Co.
Midland, MI

DuPont Instruments
Wilmington, DE

DuPont de Nemours & Co.
Wilmington, DE

Eastman Kodak Co.
Rochester, NY

E.G. & G. Idaho Inc.
Idaho Falls, ID

Electric Furnace Co.
Salem, OH

Electronic Technology
Hanscom Air Force Base, MA

El Paso Products Co.
Odessa, TX

Emerson Electric Inc.
St. Louis, MO

Emory University
Atlanta, GA

Energy Conservation System
Warren, MI

Energy Resources Co.
Cambridge, MA

Engelhard Chemical Corp.
Carteret, NJ

Engineering Systems Co.
Damascus, MD

Enirex Corp.
Patterson, NJ

Environment Information Center
New York, NY

E-Systems Inc.
Greenville, TX

Explosive Technology
Fairfield, CA

Exxon Nuclear Co.
Richland, WA

Exxon Prod. Research Co.
Houston, TX

Exxon Research Center
Linden, NJ

Fairchield Space & Electronics Co.
Germantown, MD

Fiber Materials, Inc.
Biddeford, MA

Fluids Systems Laboratory
West Lafayette, IN

Ford Aerospace Co.
Newport Beach, CA

Ford Aerospace Corp.
Palo Alto, CA

Ford Motor Co.
Detroit, MI

Forester-Monell Engr. Associates, Inc.
Colorado Springs, CO

Foundation Sciences, Inc.
Portland, OR

Foxboro Co.
Foxboro, MA

FWG Associates
Tullahoma, TN

Gale Research Co.
Detroit, MI

Garrett Corp.
Los Angeles, CA

General American Co.
Niles, IL

General Atomic Co.
San Diego, CA

General Dynamics/Convair
San Diego, CA

General Dynamics Corp.
Pomona, CA

General Electric Co.
Cleveland, OH

General Electric Co.
Hendersonville, TN

General Electric Co.
Philadelphia, PA

General Electric Co.
San Jose, CA

General Electric Co.
Syracuse, NY

General Electric Co.
Worthington, OH

General Electric Research Laboratory
Schenectady, NY

General Electric Space Division
Cincinnati, OH

General Foods Corp.
Tarrytown, NY

General Motors Corp.
Indianapolis, IN

General Motors Technical Center
Warren, MI

General Research Corp.
McLean, VA

General Telephone & Electronics Labs.
Waltham, MA

Georgia Institute of Technology
Atlanta, GA

Georgia Power Co.
Forest Park, GA

Gillette Co.
Boston, MA

Global Engr. Documentation Services, Inc.
Santa Ana, CA

Goodyear Aerospace Inc.
Akron, OH

Goddard Space Flight Center
Greenbelt, MD

Gould Inc.
El Monte, CA

GPK Products Inc.
Fargo, ND

Grandfield Associates
Santa Barbara, CA

Great Lakes Research Corp.
Elizabethton, TN

Grumman Aerospace Corp.
Bethpage, NY

Guest Associates
Huntsville, AL

Gulf Science & Technology Co.
Pittsburgh, PA

Hadden Group Inc.
Miami, FL

Hague International
South Portland, ME

Harris Thermal Transfer Products, Inc.
St. Tualatin, OR

Harrison Radiator Division/GM Corp.
Lockport, NY

Hercules Inc.
Magna, UT

Hercules Inc.
Washington, PA

Hewett-Packard Inc.
Boise, ID

Hewett-Packard Co.
Palo Alto, CA

Hitco Corp.
Gardena, CA

Honeywell Radiation Center
Lexington, MA

Honeywell Research Center
Bloomington, MN

Hooker Chemical Co.
Niagara Falls, NY

Horizons Research Inc.
Cleveland, OH

Hughes Aircraft Co.
Culver City, CA

Hughes Research Library
Malibu, CA

Huntington Alloys, Inc.
Huntington, WV

IBM Corp.
Columbus, OH

IBM Corp.
Poughkeepsie, NY

IBM Corp.
Raleigh, NC

IBM Corp.
San Jose, CA

IBM/Materials Laboratory
Endicott, NY

Idaho State University
Pocatello, ID

Illinois State Water Survey
Urbana, IL

Indiana University
Bloomington, IN

Indium Corp. of America
Utica, NY

Indland Division/GM Corp.
Dayton, OH

Ingersol Rand Research Inc.
Princeton, NJ

Inland Steel Research Laboratory
E. Chicago, IN

Institute of Gas Technology
Chicago, IL

International Applied Physics Inc.
Dayton, OH

The International Nickel Co.
Suffern, NY

Interpace Inc.
Los Angeles, CA

Iowa State University
Ames, IA

Irons & Sears
Washington, DC

IRTA Corp.
San Diego, CA

ITEX Corp.
Lexington, MA

ITEK Corp.
Sunnyvale, CA

ITT Research Institute
Chicago, IL

Jet Propulsion Laboratory
Pasadena, CA

John Deere Technical Center
Moline, IL

John Hopkins University
Baltimore, MD

John Hopkins University
Laurel, MD

Kanthal Corp.
Bethel, CT

KAWECKI BERYLCO Industries Inc.
Reading, PA

Kent State University
Ashtabula, OH

Keystone Carbon Company
St. Marys, PA

LAND Instruments Inc.
Tullytown, PA

Lamar University
Beaumont, TX

Langley Research Center
Hampton, VA

Laser Analytics, Inc.
Lexington, MA

Lawrence Berkeley Laboratory
Berkeley, CA

Lawrence Livermore Laboratory
Livermore, CA

LEAR-SIEGLAR, Inc.
Grand Rapids, MI

Libby Owens Ford Co.
Toledo, OH

Library of Congress
Science and Technology Division
Washington, DC

Lockheed Corp.
Burbank, CA

Lockheed Missile & Space Co.
Huntsville, AL

Lockheed Missiles & Space Co.
Sunnyvale, CA

Los Alamos Scientific Laboratories
Los Alamos, NM

LUWA Corp.
Charlott, NC

Marathon Oil Co.
Littleton, CO

Marquardt Co.
Van Nuys, CA

Marsh Products, Inc.
Batavia, IL

Marshall Space Flight Center
Huntsville, AL

Martin Marietta Corp.
Baltimore, MD

Martin Marietta Corp.
Orland, FL

Massachusetts Institute of Technology
Cambridge, MA

Massey Engineering
Fort Atkinson, WI

Materials Research Corp.
Orangeburg, NY

Materials Research Corp.
Pearl River, NY

Materials Science Corp.
Blue Bell, PA

McDonald Astronautics Co.
St. Louis, MO

McDonnell Douglas Corp.
St. Louis, MO

McGraw Edison Co.
Columbia, MO

Mechanical Technology Inc.
Latham, NY

Metals Research Corp.
Waterbury, CT

Metals Research Laboratory
New Haven, CT

Micropac Industries, Inc.
Garland, TX

Midwest Library Service
Maryland Heights, MO

Millersville State College
Millersville, PA

Mission Research Center
Santa Barbara, CA

MIT Lincoln Laboratories
Lexington, MA

Montana College of Mining, Science,
and Technology
Butte, MT

Montana Energy Institute Inc.
Butte, MT

Montana State University
Bozeman, MT

NASA Ames Research Center
Moffett Field, CA

NASA Lewis Research Center
Cleveland, OH

Nashua Corp.
Nashua, NH

National Association of Home Builders
Rockville, MD

National Bureau of Standards
Washington, DC

National Homes Corp.
Lafayette, IN

National Institute of Health
Bethesda, MD

National Materials Advisory Board/NAS
Washington, DC

National Metallizing Division
Cranbury, NJ

National Oceanic-Atmos. Administration
Boulder, CO

National Science Foundation
Washington, DC

National Semiconductor Corp.
Santa Clara, CA

National Water Lift Co.
Kalamazoo, MI

Naval Air Development Center
Warmister, PA

Naval Construction Battalion Center
Port Hueneme, CA

Naval Material Command
Washington, DC

Naval Research Laboratory
Washington, DC

Naval Ship R & D Center
Annapolis, MD

Naval Surface Weapons Center
Silver Springs, MD

Naval Undersea Center
San Diego, CA

Naval Underwater Systems Command
Newport, RI

Naval Weapons Center
China Lake, CA

Naval Weapons Support Center
Crane, IN

New England Research Center
Sudbury, MA

Newport Metals Co.
Newport, RI

Night Vision Laboratory
Fort Belvoir, VA

NL Industries
Niagra Falls, NY

Northrop Corp. Aircraft Gp.
Hawthorne, CA

NWI International
La Grange, IL

Oak Ridge National Laboratories
Oak Ridge, TN

Occidental Chemical Co.
Plainview, TX

Occidental Research Corp.
Irvine, CA

O'Donnall & Associates
Pittsburgh, PA

Ohio State University
Columbus, OH

Oklahoma State University
Stillwater, OK

Old Dominion University
Norfolk, VA

Olin Corp.
New Haven, CT

Owens Corning Fiberglass Co.
Granville, OH

Pacific Missile Test Center
Point Mugu, CA

PECO Manufacturing Co.
Portland, OR

Pennsylvania State University
University Park, PA

Pennwalt Corp.
King of Prussia, PA

Perkin-Elmer Corp.
Norwalk, CT

Philips Laboratory
Briarcliff Manner, NY

Phillips Chemical Co.
Phillips, TX

Phillips Petroleum Co.
Bartlesville, OK

Picatinny Arsenal
Dover, NJ

Picker Dunlee Corp.
Bellwood, IL

Polycold Systems Inc.
San Rafael, CA

PPG Industries
Barberton, OH

PPG Industries
Corpus Christi, TX

PPG Industries
Pittsburgh, PA

PPG Industries
Shelby, NC

Pratt and Whitney Aircraft Co.
E. Hartford, CT

Pratt and Whitney Aircraft Co.
West Palm Beach, FL

Princeton Combustion Research Laboratory
Princeton, NJ

Princeton University
Princeton, NJ

Pullman Kellogg Co.
Houston, TX

Purdue University
West Lafayette, IN

Pyrometer Instrumentation
North Vale, NJ

Rand Corp.
Santa Monica, CA

Raytheon Corp.
Bedford, MA

Raytheon Corp.
Wayland, MA

Raytek, Inc.
Mountain View, CA

RCA Astro-Electronics
Princeton, NJ

RCA Corp.
Indianapolis, IN

Rensselaer Polytechnic Institute
Troy, NY

Reynolds Metals Co.
Richmond, VA

Rice University
Houston, TX

Richardson Co.
Melrose Park, IL

Rockwell International Corp.
Downey, CA

Rogers Corp.
Rogers, CT

Roll Manufacturing Institute
Pittsburgh, PA

Rovac Corp.
Rockledge, FL

Salem Furnace Co.
Pittsburgh, PA

Sanders Associates, Inc.
Nashua, NH

Sandia Laboratories
Albuquerque, NM

Sandy Hill Co.
Hudson Falls, NY

Santa Barbara Research Center
Gobieta, CA

Scandinavian Documentation Center
Washington, DC

Science Application, Inc.
McLean, VA

Smithsonian Scientific Information
Exchange, Inc.
Washington, DC

Solar Energy Laboratory
Houston, TX

Solar Energy Laboratory
Madison, WI

Solar Energy Research
Golden, CO

Solar Power Corp.
North Billerica, MA

Solar Turbines International
San Diego, CA

SPERRY Flight Systems
Phoenix, AZ

SPERRY Rand Corp.
Jackson, MS

STACO Inc.
Dayton, OH

Standard Oil Co.
Cleveland, OH

Standard Oil Research Center
Naperville, IL

Stanford Research Institute
Menlo Park, CA

Stanford University
Stanford, CA

State University of New York
Plattsburgh, NY

Stauffer Chemical Co.
Dobbs Ferry, NY

Stellite Co.
Kokomo, IN

Stevens Institute of Technology
Hoboken, NJ

Structural Composites Industries, Inc.
Azusa, CA

Southern Illinois University
Edwardsville, IL

Syracuse University
Syracuse, NY

Systems Consultants
Rosslyn, VA

Technical Information Center/TRW Systems
Redondo Beach, CA

Technicon Corp.
Tarrington, NY

Technology Information Sources Center
Los Angeles, CA

Tekronix, Inc.
Beaverton, OR

Teledyne Energy Systems
Baltimore, MD

Teledyne Rodney Metals
New Bedford, MA

Teledyne Systems Co.
Northridge, CA

Teledyne Turbine Engines
Toledo, OH

Teledyne Vasco
Latrobe, PA

Tenneco Chemicals
Piscataway, NJ

TERATEK Co.
Salt Lake City, UT

Texas Instruments, Inc.
Dallas, TX

Thermax Systems Inc.
Costa Mesa, CA

Thiokol, Inc.
Brigham City, UT

Timex Corp.
Cupertino, CA

Titanium Metals Corp.
Pittsburgh, PA

Total Information
Rochester, NY

Total Systems Inc.
Downers Grove, IL

TRACOR, Inc.
Austin, TX

TRW Systems
Redondo Beach, CA

TSI Inc.
St. Paul, MN

Union Carbide Corp.
Bound Brook, NJ

Union Carbide Corp.
Indianapolis, IN

Union Carbide Corp.
Oak Ridge, TN

Union Carbide Corp.
Paducah, KY

Union Oil Co.
Santa Rosa, CA

United States Steel Corp.
Monroeville, PA

United Technologies Inc.
East Hartford, CT

United Technology Corp.
Middletown, CT

University of Arkansas
Fayetteville, AR

University of Arizona
Tucson, AZ

University of California
Berkeley, CA

University of California
Davis, CA

University of California
Los Angeles, CA

University of Colorado
Boulder, CO

University of Dayton
Dayton, OH

University of Delaware
Neward, DE

University of Hawaii
Honolulu, Hawaii

University of Illinois
Urbana, IL

University of Kentucky
Lexington, KY

University of Louisville
Louisville, KY

University of Maryland
College Park, MD

University of Michigan
Ann Arbor, MI

University of Minnesota
Minneapolis, MN

University of Missouri-Rolla
Rolla, MO

University of New Mexico
Albuquerque, NM

University of North Carolina
Chapel Hill, NC

University of North Dakota
Grand Forks, ND

University of Puerto Rico
Mayagnez, Puerto Rico

University of Rhode Island
Kingston, RI

University of Rochester
Rochester, NY

University of South Florida
Tampa, FL

University of Southern California
Los Angeles, CA

University of Texas
Austin, TX

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